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On Our Cover:
The cover, saluting the AHS 53rd Annual Forum and
Technology Display, was designed by Jon-Eric Eaton,
Tyler Business Services.

Designed and produced by Tyler Business Services.

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One of our members, after perusing the FORUM 53 Program, remarked that “there is just too much going on at this show.” We took the remark as a compliment. (We’ve learned to do that.) FORUM 53 is a departure for the Society in several ways. First it is actually taking place in a new and attractive venue — the beach. (Virginia Beach, VA to be exact.) It always seemed to me that HAI had the right formula for a successful meeting — have it someplace warm and interesting and they will come. If the number of room nights booked is any indication at this point in early April, then it would appear that they are coming in droves to Virginia Beach.

Plus, we have more than 17 aircraft flying into the show that will be on display in the parking area of the Virginia Beach Convention Center. We have also re-introduced an old tradition — the AHS Grand Awards Banquet which will be held at the venerable oceanfront Cavalier Hotel. Our distinguished award recipients will be honored to a backdrop of rolling surf.

Under the able direction of AHS Technical Director, Dr. Dev Banerjee, and the AHS Forum Technical Chairman, Dr. Andrew Z. Lennios, the FORUM 53 program is diverse and cutting edge. There are 160 technical presentations on a broad array of disciplines and the prodigious two-volume FORUM 53 Proceedings contains more than 1700 pages. The Opening General Session on “Affordable Vertical Lift” includes Dr. Paul G. Kaminski, Undersecretary of Defense for Acquisition & Technology; General John R. Dailey, NASA, Deputy Administrator; Rear Admiral R. Timothy Ziener, Commander, Naval Base, Norfolk; Jim Morris, Vice President and General Manager of Boeing Helicopters; Webb Joiner, Chairman, Bell Helicopter Textron; and BG Burt Tackaberry, Deputy Commanding General of the Army Aviation Center.

For those who dabble in V/TOL and big ticket programs, we have the Joint Strike Fighter ‘97 Symposium happening smack dab in the middle of the exhibit hall. This program, which drew more than 400 attendees last year, will be moderated by Maj. Gen Joseph T. Anderson, USMC, Vice Commander, Naval Air Systems Command and BG Leslie F. Kenne, USAF, Deputy Director of the JSF Program Office. Other high profile speakers include RADM Craig Steidle, USN, Director, JSF Program; Lt. Gen. Terrance R. Dake, USMC, Deputy Chief of Staff for Aviation; RADM Dennis McGinn, USN, Director, Aviation Warfare Div., BG Bruce Carlson, USAF, Director, Global Power Div; Air Vice Marshal Peter C. Norgiss, RAF, Procurement Executive, Ministry of Defense; David Wharton, Vice President and JSF Team Program Manager, Lockheed Martin; Dennis Mullenberg, JSF Program Office; Boeing Defense & Space Group; and Frank C. Gillette, JSF Manager, Pratt & Whitney. Plus, Sam Wilson, NASA Liaison for the JSF Program Office will moderate a special V/TOL/STOVL session that will explore the JSF and other programs.

Add to this provocative mix special sessions on Aviation Safety; Affordability: Design Product Definition; Affordability: Operations and Support; Military Program Manager Briefings; Rotorcraft Economics; Product Support — The Key to Affordability; and a few receptions and lunches and you have a pretty full three-day event. Like the man said, “You have a lot going on at this show.”

And there is a lot going on in this issue of Vertiflite. For all those interested in V/STOL we have the definitive piece titled, “The V/STOL Wheel of Misfortune.” Authored by Mike Hirschberg of ANSER Corp., this article tracks the history of the myriad attempts that have been made to conquer and combine high speed and vertical takeoff and landing.

For those Society members who have never attended a forum, this may be the one to try. Who knows the next time that we will be back at the beach...

L. Kim Smith
Editor
Romanian Historical Detail

This is in reply to the request of Romanian Matei Kiraly in the 1997 AHS International Directory (Vol. 43, No. 1, p. 4) regarding Stefan Apostolescu. Around 1957, Apostolescu approached me for consulting work on his helicopter project. He showed me his tandem rotor helicopter patent, focusing on the rotor head design. He also had, for comparison, an existing rotor head design and he maintained that his was much simpler and had fewer parts.

He obviously had a limited budget and I advised him the next best step was to build a whirl test stand so he could realistically compare two practical designs. I outlined a simple test program for him and provided a project cost estimate. Apostolescu later returned with an airline pilot who was interested in financing his project. The gentleman was seeking independent verification of the inventor's concept. I reviewed the program again, pointing out that only test hardware could be compared.

Following these meetings Apostolescu and I had a few follow-up phone conversations, after which I lost contact with him. I recall he had some work injury at the time and was collecting workman's compensation. He was an even-tempered individual, very committed to his project and interesting to talk with.

Among our conversations he related an anecdote I found amusing. When he left (or fled) Romania, the country was divided into many contending political factions. He found it difficult to take sides because of the violence involved in being on the wrong side. Once he was challenged by an activist who demanded his political position. Apostolescu asked the activist his party connection, after which the inventor replied that was exactly the one he was supporting.

The best known Romanian helicopter pioneer is Trajan Vuia, and I am certain Kiraly knows about him. Around 1922 he built a lateral rotor helicopter featuring two sets of coaxial rotors that were tiltable (U.S. patent 1423636). The machine was tested at Juvisy, France in March 1922, and typical of the times, with no success.

This project is detailed in Volume 2 of the 18 volume handbooks prepared for the U.S. Air Force. Microfilm copies of the complete works (on three spools) are in the possession of the AHS, Smithsonian Institution (Aeronautics Dept.) and AHS member Bernard Lindenbaum who was officially involved with the project.

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Heartfelt Thanks

Our sincere thanks to Gary P. Smith and the members of the Stratford Chapter of the AHS for their expression of kindness and generosity in their donation of $1,000 to the VFF Daniel L. Peduzzi Memorial Scholarship. We feel blessed to have such kind and caring friends and your consideration is of continuing comfort as the memory of an outstanding young man lives on. Best wishes to you and all members of the AHS Stratford Chapter.

Pete, Connie and Michael Peduzzi Fairfax Station, Virginia

AHS Fax Feedback – Name Change Revisited

I will give you my two cents worth since you requested feedback in the AHS International Directory. If you look up American in the dictionary it states “of or in America.” Since the international headquarters are in America I feel the name does not take away from the Society’s international status. Maybe the only way to keep everyone happy is to change the name to “AHS International.” That way all the old timers will know it as the American Helicopter Society and the new members, just AHS. Many companies did this type of change when they went international. Good luck! And by the way, is anyone actually complaining?

Kenneth Lauck Stratford, Connecticut

(EDITOR’S NOTE: The complaints about the Society’s name and its American prefix are at a low, constant din. Many potential international members have said that the name is a deterrent to their joining and annoys their management. We have revisited this issue and hope our members will let us know what they think and any suggestions for the name change...)

Plaudits

Somewhere in all of my changes (marriage, house buying, etc.) this fall, I misplaced my Sept/Oct Vertiflite. Only over the holidays did I find it and read it. I can’t help but think that if the AHS (us) and the AHS (the American Horticultural Society) did merge, the agricultural community may be pleased. Thanks for a great issue. I read it cover to cover in one sitting.

Bill Bigler Fairfax, Virginia

I think that the 1997 AHS International Directory is an excellent publication. It is organized well and it has extremely pertinent information on what is going on in the industry. The industry overview by both Colucci and Forecast International/DMS was very informative and the helicopter and engine specifications are comprehensive and useful. It will be hard to top next year....

Gene P. Munson Mesa, Arizona

I just ran across your web page and there is no doubt that it is one of the most informative I have ever seen. Congratulations!

By the way, this year marks my 20th consecutive year as an AHS member. I can remember wearing the AHS logo on my Army National Guard helmet visor while flying Chinos into weekend combat missions!

John Williams Fort Worth, Texas

Corrections

I enjoyed reading the 1997 AHS International Directory. I noted on p. 53 in the 1997 Military Helicopter Survey that the MH-47E was listed as being delivered to the U.S. Air Force. Actually all MH-47Es were delivered to the 160th Special Operations Aviation Regiment which is a sub unit of the U.S. Army Special Operations Command.

LTC Eric Hoffmeyr Washington, D.C.

EDITOR’S NOTE: Somehow in a cosmic computer glitch we managed to switch employers under the Employee Affiliation section in the 1997 AHS International Directory for some of our valued members. We sincerely apologize for the error. What follows is a correct listing.

Mr. Chris M. Ankrom Allison Engine Co.
Mr. Nick Blaskoski Allison Engine Co.
Mr. D. Alan Caine Allison Engine Co.
Mr. Andrew A. Cosner Allison Engine Co.
Mr. Frederick W. Dickens Allison Engine Co.
Mr. Eric Q. Dickerson Allison Engine Co.
Mr. Ben Doll Allison Engine Co.
Mr. David Eames Allison Engine Co.
Mr. Norman F. Egbert Allison Engine Co.
Mr. Gary W. Gentz Allison Engine Co.
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Mr. Michael A. Janovicz Allison Engine Co.
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Vol. 43, No. 2
moving blades designed by Hans Derschmidt. On the forward moving side of the rotor they were moved backwards, and on the backwards moving side of the rotor, the blades were moved forward. This should increase the forward speed of the helicopter up to 560 km/h. The BO 46 is now in the Helicopter Museum of Buckeburg.

Erich Brand
Unterhaching, Germany

Congratulations are in order for Mr. Todd Hodges and Eric Brand. They will both receive copies of the AHS fiftieth anniversary publication, "From da Vinci to Today and Beyond: The Top Technology Achievements in Vertical Flight History." We also appreciate the responses we received from Brent Wallace, Walter Bittner, Brad Clark, Bill Blake, Michael Fedele, and Bob Ormiston.

Editor's Note: Although we received a large number of responses to the "Can You Name It?" on p. 77 of the September/October issue of Vertiflite our astute readers somehow missed the challenge on p. 25 of that same issue. Perhaps the John Schneider challenge was just too difficult....
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Are Our Defense Priorities Keeping Pace?

by M.E. Rhett Flater
Executive Director

The Army's Force XXI live fire exercises now underway at the National Training Center at Fort Irwin emphasize once again the message of Operation Desert Storm. The nature of warfare has changed. Stated simply, war is no longer an exercise in mass. Neither sheer manpower nor bomb or artillery tonnage can be counted on to determine the outcome of future conflicts. Rather, we have entered the age of information. And the side which acquires information, and dominates it, will control the battlefield. Thus we derive the need for defense modernization.

Probably the most startling thing about the Persian Gulf War — a war remarkable for the extremely low number of allied casualties on the ground — was the effectiveness of U.S. airpower. General Norman Schwarzkopf — schooled in Vietnam — expected the air campaign to go the way of previous ones. In fact, he once dismissed the notion that airpower could do most of the fighting saying, "That's a bunch of hoo-ha." But between Vietnam and Desert Storm a significant change in aerial warfare doctrine had occurred made possible by the arrival of modern sensor, computing and satellite technologies. Its goal was to deny the enemy information needed to prosecute the war, in effect to block the enemy's access to the command, control, communications and intelligence capabilities he would need to hold his forces together.

The first mission of Operation Desert Storm was to blast open Iraqi air defenses so that tactical aircraft could attack without fear of Iraqi surface-to-air-missiles, antiaircraft artillery, or fighters. It fell to helicopters, a stepchild of aviation, to do the job. Less than an hour before the launch of Desert Storm, three MH-53J Pave Low aircraft with laser-target designators followed by nine AH-64 Apache gunships took off from Al Jouf near the border and crossed into Iraq. Using infrared capabilities, the Apaches spotted their targets — a series of key radar stations — and opened fire from a distance of 4.8 miles. Of 27 laser-guided Hellfire missiles fired at one to two second intervals, 15 found their targets within two minutes. The radar positions were demolished, and Air Force F-15s were then able to attack their targets deep in Iraq. Baghdad's ability to gather and process information and exercise command and control over its army was effectively destroyed. The allied forces proceeded to conclude the war in fewer than 100 hours. Later Schwarzkopf would assert that the win was a triumph of maneuver warfare, but those tactics would not have been possible without the early success of the Pave Lows and the Apache gunships.

If we need a reminder of the importance of battlefield information, we got it on March 20 during the Force XXI live fire exercises at Fort Irwin. A crack aggressor force attempted to surprise defensive elements after nightfall. It was modern textbook warfighting at its best. The maneuver, led by highly-trained military forces, had been carefully planned. Hidden from view by trees and terrain, still far away, the enemy unit — equipped with 45 vehicles including Abrams tanks and Bradley fighting vehicles featuring the latest technology — angled closer to the allied forces. But, suddenly, the systems of a single AH-64D Longbow Apache caught their movement. Within seconds the Apache crew had classified and prioritized every target. Simultaneously they relayed that information to the Joint Stars aircraft above the scene and to friendly ground units and aircraft nearby. The engagement was over almost as soon as it began. The "win" was impressive: forty-five aggressor vehicles destroyed with no friendly casualties.

This spring the Clinton Administration and Congress have renewed their debate on the need for military modernization. So far, it remains a third priority after "readiness" and "quality of life." In a sustained period of declining defense budgets one might ask how long this can continue. As Gilbert F. Decker, Assistant Secretary of the Army, once observed, "Today's modernization is tomorrow's readiness." We have our choice. Sooner or later, we must either pay the price of modernization — or risk paying a far more costly price in higher casualty rates. 

March/April 1991
Our Market Intelligence Services Provide a Focused View of the Aerospace/Defense Industry

These annual Market Intelligence Services cover thousands of military, commercial, business and general aviation programs worldwide, offering technical specifications, program overviews, worldwide distribution, production timetables, funding charts and ten-year production forecasts. Individual Market Intelligence Services cover military & civil fixed and rotary-wing aircraft, and retrofit & modernization programs.

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If the planned Boeing/McDonnell Douglas merger comes off, the new company will offer products across the entire spectrum of aerospace and defense markets with combined revenues exceeding $48 billion (and a current backlog of $120 billion). Driving the decision for McDonnell Douglas was the loss of the Joint Strike Fighter competition and the continued decline in large civil aircraft market share of Douglas Aircraft. The combination, which retains the Boeing name, strengthens Boeing Defense and Space Group and substantially improves Boeing’s JSF prospects. Recent announcements indicate that commercial aircraft will be consolidated in Seattle, space products in Huntington Beach, California, and tactical (including JSF) in St. Louis. But there will be no decisions about consolidation of MDHS’s Mesa and Boeing’s Philadelphia facilities until some time in the distant future. In the meantime, nothing happens until the proposal receives Federal Trade Commission and European Commission antitrust approvals — not expected until July and early August at the earliest. (Never a paper tiger, the Commission in 1991 blocked ATR’s planned acquisition of de Havilland.)

The mere size of the new company should result in significant economies of scale and could unleash another round of merger and acquisition announcements, both in the U.S. and Europe. The message: no combination is inconceivable.

Eurocopter is rebounding. Witness the HAI Heli-Expo announcement that it had concluded orders for 228 helicopters in 1996 valued at approximately $2.26 billion (not counting sales of 80 used helicopters). Sales for 1996 were stable at $1.75 billion, with 36 percent in the commercial sector and 64 percent in the military market. Currently, Eurocopter’s share of the world civil market is about 33 percent. During the show, Eurocopter displayed its sleek, new 5-seat EC120, whose first delivery is expected in the first quarter of 1998, and its 8-seat EC135, of which 41 have been ordered and 10 delivered. The EC 120, jointly produced by Eurocopter, the China National Aero-Technology Import and Export Corp (CATIC), China’s Harbin Aircraft, and Singapore Technologies, is powered by a Turbomeca Arrius 1F turboshaft engine and carries a price tag of $750,000. It will compete with the Bell 206B3. Meanwhile, the NH-90 and the Tiger have survived heavy cuts in the French and German defense budgets (to accommodate the government spending limits agreed upon in Maastricht). And the PT prototype of the NH-90 electronic warfare/transport helicopter, featuring fly-by-wire flight control, performed its first flight on March 20 in Marignane. No further European consolidation efforts appear underway at this time. Eurocopter president Jean Francois Bigay has been quoted as saying that the proposed Boeing/McDonnell Douglas merger won’t seriously affect the helicopter scene. Helicopter sales will account for only 1 percent of the unified company, and Boeing could either decide to sell the MD900 business or pursue an external growth policy and acquire Sikorsky, he notes.

“IT’s an exciting day to be an Army aviator,” said Maj. Gen. Dan Petrosky, Commanding General of the U.S. Army’s Aviation Training Center, at the McDonnell Douglas AH-64D Apache Longbow (production version) Rollout Ceremony on March 21. He had good reason, since early reports on the Army’s Force XXI live fire exercise at the National Training Center at Fort Irwin indicated that the preceding night a single AH-64D attack helicopter had detected a surprise attack and led the defense in destroying a crack, nighttime aggressor force composed of 45 vehicles. There were no friendly casualties. “The Longbow Apache demonstrated information dominance, digital connectivity, improved standoff capability, and better air support for the soldiers on the ground,” said Army Lt. Gen. John Schwartz, Commanding General of the Army’s III Corps and Fort Hood. “The tactics and the procedures shown by the AH64D were unprecedented.” Also attending the roll-out were U.S. senator John McCain; George T. Singley III, deputy director defense research & engineering, Office of the Secretary of Defense; Paul Bogosian, program executive officer, U.S. Army Aviation; and Mike Sears, President, McDonnell Douglas Aerospace. MDHC Senior Vice President Dean Borgman led the ceremonies. In his remarks, Bogosian announced that the Army Aviation/Industry team had realized savings of more than $200 million, putting the program in the forefront of the Pentagon’s acquisition reform efforts. Borgman announced that the March 17 first flight of the first production aircraft, with chief pilot Jerry Keyser and production test pilot Walt Jones at the controls, had met all expectations. MDHC has a contract to remanufacture 232 AH64A model aircraft for $1.9 billion, and plans to ramp up production from one per month to five monthly by 1999. Lockheed Martin and Northrop Grumman developed the aircraft’s fire control radar and Hellfire missile.

Negotiations began in January to amend the now-outdated 1990 Conventional Armed Forces in Europe Treaty (CFE), the cornerstone security regime in Europe. The 30 CFE states (U.S., Canada, Russia and former Soviet republics, and nearly all European countries) will enhance the treaty’s verification measures and reconfigure (or eliminate) the geographical zones that prevent unauthorized force concentrations. More important, to accommodate NATO expansion the parties will do away with the NATO/Warsaw Pact block-to-block arms
The treaty previously reduced Warsaw Pact forces to parity with the NATO alliance at 20,000 battle tanks, 30,000 armored combat vehicles, 20,000 artillery pieces, 2,000 attack helicopters, and 6,800 combat aircraft. But there is nothing sacrosanct in these numbers and, given recent strides in arms modernization, they could be reduced by one-half or more.

The European Union’s Transport Commissioner, Neil Kinnock, is proposing to create a “civil aviation safety organization” comparable to the FAA. It’s expected to be similar to the existing Joint Aviation Authorities, but should have much broader scope. In addition to approving aircraft and engine type certificates, it would determine and monitor flight safety regulations and promote European standards internationally. Stay tuned.

GKN Westland and Agusta announced the first flight of a full-mission equipped, production version EH 101 Merlin Helicopter (RN 02) at GKN Westland’s Yeovil, England facility. The second production aircraft is scheduled to fly before May and two other EH 101s are expected to be delivered by the end of the year. The EH 101 is scheduled to enter service with the Royal Navy in 1999.

Lockheed Martin and Boeing were the winners in the Joint Strike Fighter down-select decision. Since the announcement, McDonnell Douglas has teamed with Boeing in a move wholly separate from the planned merger of the two companies. Former McDonnell Douglas partner British Aerospace and Northrop Grumman, meanwhile, are being wooed by the winners, but there is no announcement in sight. The firms now embark on a $2.2 to $3.0 billion demonstration and development phase, in which they will build and test ASTOVL and CTOL versions by 2000.

The Japanese government’s procurement plans for the OH-1 (formerly, the “OH-X”), a twin-engine, tandem seat scout/reconnaissance helicopter produced by Kawasaki, are progressing on schedule. The fiscal year 1997 budget for the Japan Defense Agency (JDA) includes funds for three OH-1s at a unit price of $15.8 million. About 250 to 300 aircraft are expected to be delivered to Japanese agencies (193 to the Army) over the life of the program at a gross value approximating $1.5 billion. First delivery is expected in April 1997. Also included in the budget is funding for 16 UH/SH-60 Black Hawk/Seahawk helicopters, valued at $567.75 million, to be built by Mitsubishi under license from Sikorsky for Japanese Army, Navy and Air Force applications; and two Boeing/Kawasaki CH-47J aircraft valued at $97.86 million.

Close on the heels of Kaman’s win to provide Australia 11 SH-2G Super Seaspries for its ANZAC frigates, New Zealand’s navy announced it had selected the Seaspries to fill multipurpose roles, with first delivery scheduled for 2000. It was the second straight win over the GKN Westland Super Lynx. Cost and compatibility were factors; thus, the SH-2G’s service with US Navy reserve squadrons and easy access to spares and common maintenance facilities figured prominently. According to reports, Kaman chairman Charles Kaman is visiting Malaysia, Taiwan, Singapore and other Pacific Rim ports of call in an effort to capitalize on his company’s successes.

In remarks before the Aero Club of Washington, NASA administrator Daniel S. Goldin offered an ambitious plan to carry the U.S. aviation industry into the 21st century. During the next ten years, Goldin wants to reduce aircraft accident rates by a factor of five, triple the aviation system’s all-weather capability, reduce emissions by a factor of three, reduce noise levels by a factor of two, plus reduce the cost of air travel by 25 percent. A blueprint for rotary-wing programs is already under consideration at NASA’s centers. At the top of the list, predictably, are improvements in safety, satellite navigation capability, further research and development in noise, and engine programs focused on improved reliability and reduced emissions. “We can’t be a nation of wimps always looking for marginal improvements,” he announced.

Launches and landings: careers on the move. George David, president and chief executive officer of United Technologies Corp., has been named to succeed Robert F. Daniell as chairman on his April 29 retirement. Sikorsky vice president-government business (and AHS Chairman) Gary F. Rast has announced his retirement; his replacement in the Washington office will be Robert E. (“Too Tall”) Kenney, previously director-government business development. Also Richard Murphy, Sikorsky’s vice president-engineering, will retire; assuming his role will be Donald Gover, previously director of the S-92 program. Former RAH-66 Comanche program director Jim Morris has replaced Denton Hanford as vice president and general manager of Boeing Helicopters. Hanford will assume a senior role in Boeing Defense & Space Group. Michael M. Sears, former president of Douglas Aircraft Co., has been appointed president of McDonnell Douglas Aerospace, which includes McDonnell Douglas Helicopter Systems. Eurocopter has announced that Jean-Francois Bigay, president of Eurocopter France, will continue in that role for an additional five years, as will Eurocopter Deutschland president Dr. Siegfried Sobota. FAA Administrator David Hinson, as well as Deputy Administrator Linda Dashiel, have departed government service with no replacements in sight. Carl Vogt, former chairman of the NTSB, and retired Air Force Gen. Hansford T. Johnson are in the running.

Vol. 43, No 2
Fiscal 1998 Budget Proposal Addresses Major Rotorcraft Programs

by AHS Staff

The Clinton Administration’s Fiscal 1998 budget request unveiled in early February contains $250.7 billion in budget authority and $247.5 billion in actual spending for the Defense Department. Total budget authority is $2.1 billion or 3.4 percent less than what Congress approved in 1997. Overall procurement — $42.6 billion — declines by $2.9 billion compared to Fiscal 1997, while operations and maintenance is hiked by $5.2 billion to cover unplanned expenditures in Bosnia and the Middle East. Notably, Army Aviation procurement dropped by $1.4 billion. Once again the principle casualty is modernization. Defense spending falls well short of the $60 billion per year modernization level that military commanders say is required to sustain the current force until Fiscal 2001.

In the meantime, active duty force structure remains static at 10 Army divisions, three Marine Corps divisions, 11 large-deck Navy aircraft carriers, 10 carrier wings and 13 Air Force fighter wings. No change can be expected until after the Pentagon has issued its Quadrennial Review, which is unlikely to contain any surprises.

Here is a summary of how certain major rotorcraft programs fared:

- Osprey (Bell Helicopter Textron Inc./Boeing Defense & Space Group) - $1.1 billion. The Marines — who give the V-22 high marks for its speed, long range, and survivability — plan to buy 425 V-22s to replace its fleet of CH-46 helicopters, now entering their fourth decade of service. The Air Force will buy 50 V-22s for special operations missions; the Navy will buy an additional 48 for fleet logistics support and combat search-and-rescue. Since the Pentagon has capped V-22 production expenditures at $1 billion per year, the production run will last nearly 25 years. Congress could cut acquisition costs considerably (up to $5 billion) if it agreed to boost peak production rates to 36 from the 24 now planned.

- RAH-66 Comanche (Sikorsky Aircraft Corp./Boeing Defense & Space Group) - $282 million. In its initial QDR submission, the Army claims its determination to sustain a force of 10 active-duty divisions will take priority over modernization. This insistence on maintaining force structure remains the primary roadblock to the Army’s plans to begin fielding 1,292 Comanche scout-reconnaissance helicopters (now pushed out...
to 2006). Equipped with Longbow targeting and missile guidance systems, the Army proposes to employ the Comanche as the key command and communications node in its digitally linked combat teams. Highly stealthy (proponents claim its radar cross-section is 1/400th of the Apache's), it combines composite structures, a contoured shape, retractable landing gear and internal ordnance stowage.

- OH-58D Kiowa Warrior (Bell Helicopter Textron Inc.) - $38.8 million. A perennial favorite of the Congress because of its low cost, OH-58D armed scout procurement is routinely "plused up" as the Comanche production slides to the right. The reliable OH-58D, a remanufactured version of the OH-58A, has extensive experience in every conflict beginning with Operation Desert Storm. So far, Bell has performed 398 conversions, and more are on the way.

- AH64D Apache Longbow (McDonnell Douglas Helicopter Systems) - $525.2 million. The Apache Longbow — the only multi-year procurement program in the Army's inventory — remains on schedule and below budget. Its performance in the Army's Force XXI live fire exercises now underway at Fort Irwin's National Training Center leave no doubt that the aircraft is many times more capable than the AH64A. Plans call for 232 of the Army's existing AH64A fleet to be remanufactured into the Longbow version. McDonnell Douglas is teamed with Lockheed Martin and Northrop Grumman on the program.

- UH-60 Black Hawk (Sikorsky Aircraft Corp.) - $210.7 million. To keep the production lines at Sikorsky warm through 1999 (when the Navy will begin purchasing marinedized versions of the aircraft to replace its UH-1Ns), the Army will buy 18 Black Hawks it had not planned on. According to some reports, the money comes from funding the Army hoped to use on a service-life extension effort to modernize its fleet of CH-47 heavy lift cargo helicopters.

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Joint Strike Fighter Enters Concept Demonstration Phase

by M.E. Rhett Flater

At Boeing and Lockheed Martin, the two mega-firms remaining in the Joint Strike Fighter Program, engineering teams are at work around-the-clock putting the finishing touches on competing prototype designs. During the concept demonstration phase of the program now underway, both firms will build two full-scale flying prototypes — one in Marine Corps' STOVL configuration and the other sequentially fitted to demonstrate Air Force and Navy requirements. Rollout for all four aircraft is scheduled for 1999 in time to begin formal flight tests in March 2000. The Pentagon will then select a single manufacturer in 2001 for engineering and manufacturing development.

The single-seat, single-engine Joint Strike Fighter will be a three-service family of next-generation aircraft built around a common core airframe design. The Marine Corps version will be a short takeoff and vertical landing (STOVL) replacement for the AV-8B Harrier and the UK Royal Navy's Sea Harrier, while the Navy variant will be a stealthy, carrier-based attack replacement for older F-14s and F-18s. JSF will complement the Navy's newer F-18E/F. The Air Force variant, on the other hand, will replace the service's F-16 and A-10 aircraft and complement its F22 strategic fighter.

The Biggest Hurdle

Most observers agree that the biggest program hurdle is propulsion. Explains JSF program director RADM Craig E. Steidle, "I personally think the full integration of the propulsion and flight control system is the most risky element." Pratt & Whitney, selected by both Boeing and Lockheed Martin to power the JSF, is defining two versions of its F119 turbofan to meet the schedule for the concept demonstration phase. The most powerful version, said to be rated at about 35,000 lb thrust, is being developed for Boeing's direct lift design. The fan being fitted to the engine is reported to be 30 percent more efficient.

(Business JSF) The Navy variant of the Boeing Joint Strike Fighter design landing on an aircraft carrier.
While the Boeing STOVL variant has two Harrier-like main lift nozzles, the corresponding version of the Lockheed Martin aircraft will be fitted with a three-bearing nozzle to vector the main engine thrust. Engine power to the shaft-driven lift fan will be modulated by varying the main exhaust nozzle area. Both main and lift nozzles on the Lockheed Martin version permit engine thrust to be vectored forward by 20 degrees.

**Program Focus on Affordability**

Affordability continues to be the program’s principal focus, with production cost targets for the three variants targeted at $28 billion for the basic version, $35 billion for the STOVL variant and $38 billion for the carrier-capable version. According to Steidle, “The most important thing we’re doing right now is cost and operational tradeoff analyses.” Use of off-the-shelf components for the prototypes and successful integration of a number of key component and subsystems especially designed for JSF is considered critical to cost containment efforts.

International participation is growing steadily. The UK has contributed $200 million toward the $2.2 billion cost of the concept demonstration phase. Recently, Norway, the Netherlands and Denmark signed a memorandum of understanding to participate in JSF development and contributed $30 million. Canada, Australia and Turkey have also expressed interest. British Aerospace, which was partnered with McDonnell Douglas, is reported to be negotiating for a major role with both Boeing and Lockheed. Rolls Royce is performing propulsion work for both. Its subsidiary Allison is supporting GE Aircraft Engines on an alternative JSF engine based on GE’s F110, which should enter EMD in Fiscal Year 2004.

While the Lockheed Martin proposal won recognition during the concept definition phase as the lowest risk alternative, the planned merger next summer of Boeing and McDonnell Douglas strengthens Boeing’s prospects. The St. Louis-based firm brings expertise in designing carrier-based aircraft, such as the F/A-18C/D and the new F/A-18E/F. It also builds the AV-8B Harrier, the only VSTOL fighter currently in production. In February, McDonnell Douglas signed a formal agreement to assist Boeing on JSF and shipped 50 engineers to Seattle, which ensures Boeing of McDonnell Douglas support regardless of the outcome of the merger.

In its Fiscal 1998 budget request, the Defense Department sought $930.9 million for JSF. In previous years, Congress appropriated $1 billion of the $3.3 billion projected cost of the development program. JSF will likely come under heavier scrutiny as the program nears production, given the concern of some congressional members over the projected spending bubble generated by the combined F-18E/F, the F-22 and the JSF programs. For Boeing, Lockheed Martin and their team members, the stakes are considerable. The winner of the competition could receive an order for 2,800 aircraft or more. At current year prices, that could bring total program value to roughly $200 billion, eclipsing every other military spending program this decade.
Letter From Europe

by Elfyn ap Rees

When Kim Smith and Rhett Flater invited me to join the Veriflite team and contribute news from Europe, my first reaction was to be flattered and, then panic. As the publisher and editor of two rotary-wing news magazines, plus involvement with various rotary-wing organizations too numerous to list here, could I really find the time?

There again, Europe is a major contributor to the international rotorcraft scene and, with the AHS wanting to become more international in its outlook and coverage, maybe finding the time was less important than making sure European happenings got some coverage.

In a nutshell, that’s why this column is before you and why this may be the first and last time it includes a chatty introduction. What you want to know, I’m sure, is the news. Read on!

GKN Westland Helicopters contracted with the Radar Systems Div. of GEC-Marconi Avionics to supply Seaspray 3000 radars for the seven Super Lynx helicopters ordered for the German Navy late last year. This order takes the total number of Seaspray radars ordered to date to more than 500. Seaspray Mk 1 radars are already in service with the German Navy in its existing fleet of Lynx Mk 88 helicopters, and discussions on upgrading these radars to achieve a common standard are underway. Seaspray 3000 is also in service with the German Navy in their Sea King Mk 41 helicopter fleet. This latest order will enable the naval air arm (the Marineflieger) to take full advantage of the use of Seaspray 3000 as the common radar standard across its helicopter fleet. The Radar Systems Division is also currently engaged in the upgrading of Seaspray Mk 1 radars in the Brazilian Navy Lynx Mk 21 and UK Royal Navy Lynx HM Mk 8 and supplying Blue Kestrel 5000 radars to the UK Royal Navy for its Merlin HM Mk 1 helicopters.

GEC Marconi and Finmeccanica have agreed to study joint cooperation and integration of their defense-related divisions in the UK and Italy. Joint ventures would allow the marketing of complete weapon systems without bringing in outside subcontractors for subsystems.

A new ultralight two-seat helicopter is under development in Belgium, powered by a 65 hp Rotax 582 engine and with an empty weight of 150 kg (331 lb). The all-composite prototype is being developed at Moorslede by Masquito Helicopters which was set up by designers Paul and Stafan Maschelein. Some 25 hours of flight testing had been completed by early March. The anticipated selling price is £425 1.5 million.

BP Chemicals Ltd Aerospace Composites, Bristol, has been awarded a contract from Yeovil-based Normalair Garrett (NGL) for the manufacture and supply of Sonobuoy Carousel Dispensers for the Royal Navy’s EH101 Merlin helicopters. Subsequently they may be used on the Nimrod 2000 anti-submarine aircraft and, possibly, on the NH90 helicopter.

The initial order is for 70 units for the EH101, while deliveries for the Nimrod 2000 and the NH90 are scheduled to extend into the year 2000 and beyond. Aerospace Composites already successfully manufactures the nose cone for the EH101 helicopter, and work on the new contract for the EH101 will start immediately with first deliveries commencing mid-year. Current work at the company also includes manufacturing radomes for the Longbow Fire Control Radar which will be featured on the British Army’s Apache helicopters.

Cabair Helicopters, based at the outer London Elstree Aerodrome, expects to increase its helicopter tourism business this year (following uptake forecasts of tourism growth using Eurocopter AS355F Twin Squirrels. The company hopes to fly more than 1,000 passengers on a 30-minute tour of London sightseeing spots. Each person will receive a souvenir video of the flight as part of the £125 package cost. Cabair has been operating the sightseeing tour since 1992.

Lucas Varity plc has announced the intended disposal of Lucas Aerospace Fuel and Mechanical Systems (FMS) as part of its restructuring program first released by the group last December. FMS has been part of the Lucas Aerospace division since 1989, when Lucas acquired Bronzavi Air Equipment. It designs and manufactures low pressure fuel engine controls and hydro-mechanical equipment, primarily for military applications.
The company, based in Paris, employs approximately 300 people.

The GKN Group reported an “outstanding year” in its Aerospace and Special Vehicles Div. as part of its overall 1996 financial results. The division, which includes GKN-Westland Helicopters, increased sales from 1995 by 28% to £961 million and operating profit increased 31% to £85 million.

Following the handover of the first production EH101 Merlin helicopter last year, four aircraft are expected to be delivered in 1997 and the first of 22 EH101 Support variants for the Royal Air Force are now in the jigs at the Yeovil factory. Seven of the nine new aircraft slated for delivery to the Brazilian Navy are currently test flying and seven new Super Lynxes are on order for the German Navy. Brazil has also contracted to upgrade five early Lynxes to Super Lynx configurations, and similar contracts are expected in the near term from Denmark and Germany.

On March 4th, Eurocopter conducted a 70-minute first flight of the AS350-B3 variant of the single-engined Ecureuil. This aircraft is expected to replace the SA315B Lama and the lower-powered AS350Bs for hot/high and external load operations. Powered by an 847 shp Turbomeca Arriel 2B engine which is equipped with FADEC (fully automatic digital engine control) and includes automatic start up and optimized performance, the AS350-B3 has the same empty weight as the AS350-B2, but it will be able to slingload of up to 1,400 kg (3,086 lb). The target performance, which will be achievable with the new variant, is that one pilot, with fuel for one hour, will be able to deliver or collect a 240 kg (529 lb.) load at an altitude of nearly 6,096 m (20,000 ft.) (This is the same performance as the Lama.) However, the AS350-B3 will cruise faster at 259 kph (140 kts), and it will also have considerably reduced direct operating costs because it incorporates the latest technology.

The new variant also introduces a modernized instrument panel featuring dual flat panel color Vehicle and Engine Multifunction Displays (VEMDs), developed for the EC120. Using symbology that mimics traditional readouts, the VEMD displays the main engine and vehicle parameters, along with a First Limitation Indication (FLI), presenting all relevant information in the form of a symbology display in conjunction with an FLI-alert audio warning system. This substantially lightens the cockpit workload. The VEMD also performs a number of ancillary functions such as computing takeoff weights, monitoring engine power, and recording cycles and limit-value overloads. It thus provides an important safety factor, ensuring more effective mission execution, especially with external loads.

Other improvements on the AS350-B3 include engine control via a twistgrip on the pilot’s collective pitch lever, a main gearbox upgraded to 670 shp, and adoption of the twin-engine version’s tail rotor. Optional equipment includes a downward-looking window, an electrically controlled viewing mirror, and left-hand piloting.

French DGAC certification is expected in November 1997, with delivery of the first machines planned for the following month. Three AS350-B3s have already been ordered in Europe. To date, more than 2,000 single-engine AS350/AS550 have been sold in 62 countries to 860 customers, representing an aggregate 7.5 million flight hours.

The Netherlands Civil Aviation Authority has joined with the UK to study the Norwegian satellite-based modified automatic dependent surveillance (M-ADS) program, currently being evaluated in the Norwegian sector of the North Sea, for positive air traffic control of offshore helicopter operations.

Like the UK sector, the Netherlands has a considerable amount of low-level military flying conflicting with helicopter operations. Currently the M-ADS is being evaluated on board a Helicopter Service Eurocopter AS332L1 Super Puma and a Sikorsky S-61N, although it is scheduled to be installed in two additional Super Pumas, including an L2, and an S76C+ of Norsk Helikopter over the next four months. This will extend the range of helicopter types evaluated, as well as allow tests to be carried out in more northern latitudes. A further five helicopters are likely to be equipped with the system by the year end.

Eurocopter plans to modify the first prototype EC135 into a military EC635 demonstrator, installing cockpit and cabin floor armour supplied by Armour of America Inc. Flight trials are expected to begin at the Eurocopter Deutschland facilities in June. The EC635 is currently being promoted to meet a South African Air Force requirement for a new utility/scout helicopter to replace the Aerospatiale SA316B and it is also being offered to the German Army as a twin-engined training and utility helicopter.

Now that the 28-day period for appeal has expired without a challenge, it would appear that the recent and most imaginative attempt to provide a city heliport in central London has failed. The Thames Heliport PLC proposal called for a floating heliport, which would actually cruise along a 16 km (10 mile) section of the River Thames, stopping periodically at each of 22 pre-determined points in mid-river to allow helicopter operations. To overcome known planning criteria, the heliport would neither moor to a bank or drop anchor but rely on thrusters to maintain station. Additionally, no one site would be used more than 28 times in a calendar year. Inevitably the company’s plans were opposed by the local Councils bordering the river, and the argument ended up in the
Court of Appeals last November.

Among the questions to be determined was whether the water and air above the river bed could be included in planning law as part of the land for change of use or development purposes, and whether the 28 day rule (under which a site can be used without planning permission) applied. The conclusion reached by the three Lords of Justice who heard the appeal was that operation of the heliport in these circumstances could constitute a change of use of land, but they reached no definitive conclusion.

Thames Heliport PLC was therefore left with no guarantees and with the risk that if the company proceeded it could face enforcement action from one or more of the local authorities. Under these circumstances, it seems doubtful that the plans will proceed.

As expected the UK helicopter fatal accident rate rose last year, repeating the 1994 statistics (2.2 per 100,000 hours) and reversing what had been a sharp decline since 1994. All four fatal accidents in 1996 took place in the last quarter and all involved turbine helicopters, mostly flown by commercial pilots, under conditions involving bad weather and/or darkness. The rolling 10 year cause analysis shows that, since the beginning of 1995, 22% of UK helicopter accidents have involved low flying, 15% controlled flight into terrain, and 11% loss of control IMC.

U.S. statistics for 1996 included 16 fatal accidents involving turbine-engine helicopters, the same number as in 1995, but with a marginal increase in fatalities, from 34 to 36. Total accidents for turbine helicopters increased 15% from 78 to 90, with 85% in both years involving single, as opposed to twin engine helicopters.

The UK Ministry of Defense has now adopted the Racal Automatic Voice Alerting Device (AVAD) for all variants of the Westland Sea King helicopter, following initial installation in the Royal Air Force search and rescue variant. A £3 million contract will now see the system being installed in the four Royal Navy variants, including the Mk4 commando assault version.

AVAD is able to carry messages which, through tone, can convey the urgency of a potentially dangerous situation or aircraft fault. Messages may include instructions to correct or check low height, rotor rpm, voltages and pressures. UK civil helicopter operators engaged in offshore operations are already required to be fitted with a voice warning device for low height indication.

NATO Helicopter Industries (NHI) is expected to submit proposals for the production launch of the NH90 helicopter by the end of April, clearing the way for the signing of a production phase agreement later this year. Both Germany and the Netherlands require initial deliveries in 2003, to replace the Bell UH-1D and Westland Lynx, respectively. The Netherlands wants 20 NH90 naval variants and France expects 27 aircraft deliveries to start in 2005, and Germany expects 38 aircraft beginning in 2007. Italy wants 64 aircraft, but has yet to specify a delivery schedule. Meanwhile, start of deliveries to Germany of 205 TTH transport variants will likely be followed by 160 aircraft required by Italy since France has postponed its 133 TTH90s until 2011.

For the Netherlands, being the launch customer for the NH90 presents special technical concerns, specifically the on-schedule development of the naval mission and weapon systems. One requirement for a production phase agreement will be a commitment by industry to meet any technical risks.

The Belgian Air Force has budgeted BFr 130 million in its FY1997-99 plans to purchase a used Westland Sea King helicopter to strengthen its search and rescue service. The Air Force currently operates five upgraded Sea King Mk48A from Koksijde on offshore and inland SAR work.

FPT Industries plans to design and manufacture a new emergency flotation system for the Sikorsky H-60 family, with the first kits due for delivery in the last quarter of 1997.

The system is based on multiple flotation bags, three around the nose section, and two aft, and should overcome problems identified by the US Navy with the original system. The service found that when the kit was inflated it proved difficult for passengers to exit the ditched aircraft. The US Navy has been operating its Seahawk variant without flotation equipment but this has also led to criticism and increased the fatality and injury risk to the pilot and copilot. This was due to the tendency of the design to "dig in" nose first during ditching, with consequent damage to the cockpit structure and immediate flooding.

The new flotation system is expected to answer these criticisms and enhance sales prospects for the H-60, particularly in Canada where Sikorsky is involved in the search and rescue helicopter competition. The equipment is also likely to be installed on the new US Navy CH-60 variant, and will be retro-fittable on earlier SH-60 and HH-60 versions that also operate over water.

"Letter from Europe" is based on selected news drawn from the international pages of HeliData News & Classified, the fortnightly newsletter published by the author and covering the latest worldwide aspects of military and civil helicopter development and operation. For subscription details (26 copies annually by E-Mail or hard copy air mailed) contact: Avia Press Associates,75 Elm Tree Road, Locking,Weston-super-Mare, North Somerset, England, BS24 8EL, Fax: +44-1934-822400, E-Mail: 106356.401@compuserve.com
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Systems Integration
What Night Stalkers Fly —
The Helicopters of the 160th Special Operations Aviation Regiment

by Frank Colucci

The new MH-60K has an extendable aerial refueling probe to take gas from C-130 tankers. The new Special Operations Aircraft also has a multimode radar and FLIR on its nose, satellite communications dome on its back, and an elevated External Tank System to preserve a clear field of fire from the windows. (Sikorsky Aircraft)

The 160th SOAR is a highly trained aviation company that operates aircraft specifically designed for special operations. The helicopters they fly are extensively modified in accelerated development cycles for the most demanding missions. Those aircraft have evolved since 1980, and they represent the leading edge of military helicopter systems integration.

Special Operations by US Army definition are missions with high personal risk and high operational or strategic payoff. They are often politically sensitive and in most cases offer no second chance. While a conventional attack or utility helicopter company might legitimately abort a mission due to bad weather, equipment failure, or heavy resistance, Special Operations aviators press on. The motto of the 160th SOAR is simply Anytime, Anywhere, Night Stalkers Don’t Quit.

Operational secrecy is essential to the success of most Special Operations, and the Night Stalkers prefer to fly at night and low altitude to avoid detection. The customers of the 160th are Army Rangers, Navy SEALs, and other joint-service Special Operations Forces (SOF). In the words of one Night Stalker, We don’t put anything on the aircraft that doesn’t benefit the guys we’re carrying.

Serving SOF

The 160th grew out of the need to move SOF over long distances into hostile territory. Soon after US Navy RH-53Ds failed to rescue Americans from Iran in April 1980, the Army began planning a second rescue attempt. Task Force 158 was formed with UH-60A Black Hawks and CH-47C Chinooks drawn from the 101st Airborne Division at Fort Campbell, Kentucky, and OH-6As from the Army National Guard. It began hazardous night/low level flight training with early AN/PVS-5 night vision goggles in June 1980. Release of the Tehran embassy hostages made a second rescue mission unnecessary, but the Army decided to keep a standing Special Operations Aviation unit...
designated Task Force 160.


The 160th SOAR inventory now includes 20 AH-6 and 20 MH-6 Little Birds, 11 MH-47D and 25 MH-47E Chinnooks, and 37 MH-60L and 23 MH-60K Black Hawks. Fort Campbell, Kentucky is home to the 1st and 2nd Battalions of the 160th. Hunter Army Airfield hosts the 3rd battalion. A Black Hawk detachment is routinely based at Howard Air Force Base in Panama. The 160th keeps aircraft ready to deploy on four hours' notice in support of five regional Commander In Chiefs (CINCS), and it routinely fields training detachments of four to 12 aircraft around the world. Night Stalkers travel light with minimal support equipment, and rely on specially skilled maintainers and contractor support to keep flying. They operate in harsh environments ranging from desert hidesites to the decks of small ships.

Fort Campbell is also the home of the 160th SOAR Special Operations Aviation Training Company, and the Systems Integration and Maintenance Office (SIMO). The SIMO is the in-house development agency responsible for developing, fielding, and modernizing a unique fleet.

**Little Birds**

In preparation for a second Iranian rescue attempt in 1980, the Army evaluated both the Bell OH-58C and McDonnell Douglas OH-6A as small, deployable attack and utility helicopters. The OH-6 proved easier to load into a C-130 turboprop, and the first Special Operations Little Birds were drawn from the National Guard. The 160th no longer has operational control of a Guard unit, but the long-secret Little Birds remain versatile and important tools in light attack and assault companies.

New-build AH-6 attack and MH-6 utility birds based on the T-tailed MD500D were reportedly first purchased in 1981 under the codename heartspr. The AH-6 never completed formal Army airworthiness qualification until years after it joined the 160th. Six AH-6s were deployed by C-130 to fight for the first time in Operation Urgent Fury on Grenada in October 1983. Little Birds attacked the Iranian Air as it lay mines in the Persian Gulf in September, 1987, strafed the headquarters of the Panamanian Defense Forces in December 1989, and were rumored active in Baghdad in January 1991. An MH-6 pulled wounded Black Hawk crewmembers from the midst of a daylight firefight in Mogadishu, Somalia in 1993.

Easy to deploy and tough to detect, the quiet Little Bird provides responsive fire support and air mobility with the lowest maintenance-to-flight hour ratio in the Night Stalker inventory. It is the cheap-to-fly navigation trainer of the 160th's Green Platoon. The AH-6/MH-6 can be manhandled down the ramp of a C-130 by a single soldier and ready to fly in seven minutes. Today's Little Bird has a payload around 1,800 lb. Maximum wartime infiltration radius is 280 nm with a 65 gal Robertson auxiliary fuel system in the aft cabin. The MH-6 can also carry 30 gal Half-Round Tanks on each side. The fold-up tanks or simpler People Planks are ridden by Special Forces troops. The 160th is now planning to replace the crashworthy commercial fuel cells of the A/MH-6 with crashworthy, ballistically tolerant tanks from OH-6As.

The two-pilot AH-6G gunship and single-pilot MH-6H transport have now been upgraded to the convertible J-model. Rigged with external seats, the MH-6J carries up to six assault troops or two snipers. With the Plank, Aerocrafter's folding two- or four- station weapons carrier, the AH-6J can be armed with a choice of weapons or equipped for hazardous environments with an 80 lb survival pack.

The weapons menu of the AH-6 is varied. In seven- or 19-shot pods, the ancient 2.75 in. folding fin aircraft rocket is actually very accurate at ranges less than 1,000 m, and pilots

![The AH-6 is the attack helicopter of the Night Stalkers armed with rockets, guns, mines, or missiles. It can also carry a FLIR turret under the nose to supplement the Night Vision Goggles worn by the two pilots. (US Army)](image-url)
of the 160th practice firing single rounds at point targets. The later 70 mm Hydra 70 reaches out to 8,800 m with wide-area munitions. The Vietnam-vintage M134 7.62 mm minigun sprays 6,000 rounds a minute to a maximum effective range up to 1,000 m. The even-older 50 caliber M2 machine gun provides greater penetrating power at comparable ranges. Against hard point targets, the Lockheed-Martin AGM-114 Hellfire missile is deadly out to 8 km. The AH-6 can also fire 1R flare rockets to illuminate targets for aircrews and ground troops with night vision goggles.

The Night Stalkers have developed ways to aim weapons accurately at night. While tracer rounds provide target offset for the attack helicopter pilot, they also point out the aircraft to the enemy on the ground. Invisible to the unaided eye, the 820 to 850 nm AIM-1 laser projects a spot seen up to 4 km away through night vision goggles. The battery-operated 20 mW semiconductor laser is attached to the minigun housing or weapons mount and puts a 0.3 mili-radian dot where rounds should fall. Little Birds generally fly without cockpit doors, and a cable links the laser on the inboard stores station to the aiming switch on the pilot’s collective. Little Birds have also long used the Hughes AAQ-16 thermal imager to navigate, target, and record. The new AAQ-16D has 1, 6, and 16 X magnification and a laser designator/rangefinder for Hellfire and other weapons.

**Mission Enhanced**

For its size, the AH-6/MH-6 has a comprehensive communications/navigation suite including satellite communications capability. Special Operations aviators have long used the King KNS 660 flight management system. The cockpit computer lets the Little Bird pilot choose from Omega/VLF, TACAN, and VOR navigation aids, and now a GPS receiver. It stores mission plans and waypoints, calculates range and endurance, and shows flight data on an NVG-compatible display.

The 160th has always tried to get the most out of its Little Birds. The four-bladed OH-6A with 317 shp Allison T63-A-5A had a design gross weight of 2,100 lb. The five-bladed MH-6C with 420 shp Allison 250-C20 took takeoff gross weight of 3,200 lb. The AH-6J with 650 shp C30 has a maximum takeoff weight of 3,950 lb. Work is underway on a stretched Mission Enhanced Little Bird (MELB) with a gross weight up to 4,700 lb. The AH-6/MH-6 takes advantage of the same C30R engine improvements applied to the OH-58D including a generic Full Authority Digital Electronic Control (FADEC) from Chandler Evans. The MELB combines the six-bladed rotor system of the MD600 with a four-bladed tail rotor.

In April 1990, the Army acknowledged plans to upgrade its Little Birds with the McDonnell Douglas NOTAR No Tail Rotor system. In principle, a protected anti-torque system with less noise and no tail rotor, radar flicker meant an even less detectable helicopter safer around trees and buildings. Compared to tail rotors, NOTAR promised reduced maintenance and improved survivability. Two prototype MH-6Ns were converted by McDonnell Douglas and evaluated at Fort Campbell and Edwards Air Force Base. Maintainers...
from the 160th began training at Mesa, and plans called for up to 39 conversion kits. Unfortunately, the system so safe and successful with civil operators imposed unique penalties in Special Operations.

In SOF mission profiles, NOTAR drew more power than a tail rotor, and a promised 200 lb payload increase turned into a 400 lb payload loss. The ducted fan increased fuel consumption and reduced infiltration range. Despite the high ultimate yaw rates available with NOTAR, slower initial response to pedal inputs made it more difficult to put weapons on target and hold them there. In deployability tests, latches on the folding NOTAR tail boom were clumsy and delicate. The 160th ultimately abandoned the expensive NOTAR conversion. One of the MH-6N demonstrators will become the Mission Enhanced Little Bird prototype with upgraded dynamics and a fuselage long enough for seven or eight seats inside the helicopter. All along, the 160th has paid a premium to keep the round nose and visibility of the early Cayuse on later Little Birds.

Black Hawks

The Black Hawk was new when TF160 was first assembled in 1980 under the code name Honey Badger. It became the workhorse of the assault companies of the 160th SOAR and evolved dramatically from the simple UH-60A to today’s highly integrated MH-60K Special Operations Aircraft and armed MH-60L DAP.

Black Hawks of the 160th inserted SEALs into the Governor’s Residence on Grenada during Urgent Fury. During Operation Just Cause, three MH-60s positioned SOF troops to stop advancing Panamanian Defense Forces so the oncoming enemy could be attacked by AC-130 gunships. Black Hawks of the 160th took SOF troops to hide sites deep inside Iraq after the invasion of Kuwait in 1990. During Desert Storm in 1991, an MH-60 hurriedly extracted a Special Forces team under fire, and another made the only NVG rescue of the war when it recovered an F-16 pilot down in Iraq. MH-60s are among the US aircraft at Brindisi, Italy in support of Operation Joint Endeavor.

The basic UH-60A with General Electric T700-GE-700 engines enabled the Night Stalkers to carry up to 16 combat troops, depending on fuel load, and could be equipped with the AAQ-16 FLIR, M134 miniguns, Fastrope bars, and other Special Operations equipment. Maximum wartime infiltration radius was 358 nm with two 185 gal Robertson tanks. The MH-60L Black Hawk with -701C engines 20% more powerful than the -700s increased fuel burn and reduced infiltration radius to 256 miles. Maximum takeoff weight of the MH-60L is 20,500 lb. The standard Black Hawk External Stores Support System (ESSS) gives the MH-60L four stations for fuel or weapons. Truncated two-station wings are available to help deploy aboard C-5 Galaxy jets.

In the Army Special Operations Aviation manual, Direct Action missions call for inserting troops directly into enemy targets or into nearby landing zones, or for Special Operations aircraft to attack targets themselves. The MH-60L Direct Action Penetrator (DAP) at some point became the Defensive Action Penetrator, but it remains an ESSS Black Hawk with 30 mm Chain Guns, 7.62 mm miniguns, 19-shot rocket pods, and Hellfire missiles. Heaviest and most devastating of the DAP weapons fired so far is the AGM-65 Maverick TV, infrared, or laser-guided missile. The AESOP AAQ-16D thermal imager provides a powerful standoff sighting system for all the weapons, and a laser designator for Hellfire and Maverick. The 160th has 10 MH-60L DAP aircraft on strength and can convert the aircraft from utility to attack configuration in 30 minutes.

For long night/low altitude/adverse weather missions, the Night Stalkers have long sought to reduce crew workload with better cockpit integration. UH-60As and MH-60Ls of the 160th received the Rockwell-Collins (now Rockwell’s Avionics & Communications) CMS-80 cockpit management system. Integrated on a MILSTD 1553B databus, the navigation/communications suite with its control/display units was an impor-
tant step in helicopter avionics and a predecessor of the more integrated cockpits to come.

**MH-60K SOA**

Development of the sophisticated MH-60K was initiated in 1986 to provide a purpose-built Special Operations Aircraft (SOA) still classed as a Non-Developmental Item by the Department of Defense to save time and money. The integration challenge nevertheless lengthened the normally quick SOF development cycle. The prototype MH-60K rolled out 13 March, 1990, but the Black Hawk SOA was not declared Mission Ready until October 1995. The result is nonetheless a highly capable, long-range, night/ adverse weather penetrator with both AAQ-16 FLIR and Texas Instruments APQ-174 multimode radar tied to an advanced glass cockpit. The terrain avoidance radar was tested at 100 and 300 ft penetration altitudes at Edwards Air Force Base in late 1996 and fielded with the 160th in early 1997.

The Lockheed-Martin Integrated Avionics System (IAS) of the MH-60K and MH-47E SOA gives pilot and co-pilot access to aircraft systems, sensor imagery, navigation and communication functions, aircraft survivability equipment, and diagnostics through multifunction CRT displays with bezel and cyclic switches. AlliedSignal supplies the 6 in. square displays and display generators. Smiths Industries provides the control/display units that enable SOA pilots to enter frequencies, waypoints, and other data on the center console. The processing power in the MH-60K will make it the first operational beneficiary of the Rotorcraft Pilot's Associate. Portions of the work-reducing cognitive decision aid to may be applied to intense SOF mission profiles.

The cabin of the MH-60K sacrifices one seat for an electronics rack. Many of the other MH-60K airframe and systems changes were introduced on earlier H-60s and incorporated on the MH-60L. For example, the upturned External Tank System (ETS) from the cancelled Air Force HH-60D gives MH-60K gunners a clear field of fire and clears the Seahawk rescue hoist. The manually folded horizontal stabilator of the Seahawk helps the Army MH-60K fit Navy ships and Air Force jet transports.

*The new MH-60K Special Operations Black Hawk is tailored to long range, covert missions with air-to-air refueling capability, terrain following/terrain avoidance radar, and an Integrated Avionics Suite common to the MH-47E. (Sikorsky Aircraft)*
The MH-60K also inherited the telescoping aerial refueling probe qualified on the HH-60D, and the probe may be retrofitted to some MH-60Ls to make them compatible with Hercules tankers.

Like the MH-60L, the MH-60K has 1,900 shp General Electric T700-GE-701C turboshas, and like the Lima model, the MH-60K has the 3,400 shp improved durability gearbox taken from the SH-60B. The Special Operations Black Hawk is cleared to 24,500 lb gross weight, albeit at the expense of dynamic component life. Two 200 gal internal auxiliary tanks fit the aft cabin of the MH-60K. Wartime infiltration radius without refueling is 296 nm.

The MH-60K has the SH-60F automatic flight control system with automatic approach to a coupled hover and automatic departure modes. The avionics suite includes the ARC-201 tactical radio and AR-210 SATCOM set. The 160th will be the first unit to receive the ARC-220 HF radio with Automatic Link Establishment for reliable nap-of-the-earth communications. Harris is developing a digital map for both the MH-60K and MH-47E.

Night/low altitude operations are intended to evade the enemy, but the MH-60K has a comprehensive Aircraft Survivability Suite to detect and defeat air defense threats. The Kilo model Black Hawk has the same GE hover infrared suppressors and Tracer M130 flare/chaff dispensers worn by standard Army Black Hawks. The smart, programmable ALE-47 dispenser and AAR-2A laser detecting set were introduced in late 1996. Like UH-60s, the MH-60K carries the Sanders ALQ-144 infrared jammer. The MH-47E and MH-60K have share ITT ALQ-136(V)2 pulse and Northrop ALQ-162 continuous wave radar jammers, and Honeywell AAR-47 missile warning detectors. A Low Probability of Intercept (LPI) radar altimeter is under development for both the Black Hawk and its bigger SOF brother, the MH-47 Chinook.

**SOF Hooks**

The CH-47 joined the early Task Force 158 at the same time as the UH-60, and the big Chinook has been used much like the Black Hawk ever since. Unlike the world Army, Special Operations Aviation operates the Hook as an assault helicopter to Fastrope and fast-land troops as well as haul cargo too heavy for the Black Hawk. Rubber raiding boats can sit fully loaded in the cabin of a Chinook to float out seconds after a water landing. The same boat can be tied to the belly of a Black Hawk. The MH-47D operates at gross weights to 50,000 lb and carries up to 50 troops with a seat waiver. Wartime infiltration radius is 300 nm. Because of its size and range, the Chinook is also the preferred platform for extremely long missions or self-deployment. In 1988, two MH-47Ds flew 490 miles at night to recover an Ml-24 Hind from a remote location in Africa. When US forces invaded Panama, three MH-47Ds flew from Fort Campbell to Hurlburt Field, Florida, linked up with Air Force MH-53Js, and self-deployed to Howard Air Force Base. On the first night of Operation Desert Storm, Fat Cow MH-47s refueled AH-64 Apaches on their way to attack Iraqi air defenses.

Tearing down a Chinook for shipment aboard a C-5 wastes up to 12 hours, and reassembly and testing can take another 18 to 24 hours. MH-47s are consequently better self-deployed if the distance is less than 2,000 miles. The 160th experimented with a telescoping refueling probe in 1985. CH-47Ds equipped with 28 ft long fixed probes became operational in July 1988 and were used to deploy aircraft to Panama in 1989. Maintainers of the 160th can remove the probe from the aircraft in 20 minutes and reinstall it in 30 minutes. Probe and tanker drogue are illuminated by moveable infrared and visible spotlights in forward rotor pylons of air-refuelable Chinosok.

The first modernized CH-47D SOA joined the Army fleet in 1982, and TF160 began integrating the Rockwell-Collins cockpit management system early in the MH-47D's service life. The adverse weather avionics suite on the MH-47D included the Bendix RDR-1300 weather radar and AAQ-16 thermal imager.

**MH-47E**

Development of the dedicated
MH-47E Special Operations Chinook paralleled development of the MH-60K to share the sophisticated IAS. Displays and processors from one aircraft can be transferred to the other should the Night Stalkers have to cannibalize to complete a mission. Despite long, grueling missions, the MH-47E specification calls for 85% availability with a 90% chance of completing a 5 hour mission over a 300 nm unrefueled radius. Required overall Mean Time Between Mission Aborts is 55 flying hours for the MH-47E, nearly twice the 28 hours of the CH-47D.

The E-model Chinook carries its APQ-174 multi-mode radar in a port side pod. The long nose of the MH-47E can accommodate an optional RDR-1300 weather radar like that in some MH-47Ds.

Structurally, the MH-47E is identical to the CH-47D despite its maximum gross weight of 54,000 lb, two tons heavier than the D Model. The enormous composite sponsons of the commercial Model 234 Chinook double the fuel capacity of the CH-47D from 1,078 gal to 2,060 gal in crash-resistant, self-sealing bladders. Wartime infiltration radius is 415 nm. The longer fuel sponsons of the MH-47E made it necessary to move the front landing gear of the Chinook forward 40 in. and required software changes in the Automatic Flight Control System. The MH-47D and E both have rescue hoists for SOA formations to provide their own search-and-rescue capability.

To hike the hot-and-high and single engine emergency power of the Chinook, the MH-47E has AlliedSignal T55-GA-714 engines 12 to 38% more powerful than the -712 of the standard CH-47D. The -714 generates 2,900 shp maximum continuous and 4,000 shp emergency power at 4,000 ft and 95°F, with fuel consumption 3% lower than that of the -712. The -714 also has a more reliable phase-shift torquer developed by the Army, and it benefits from the full authority digital electronic control (FADEC). It will be retrofitted to the Army CH-47D fleet, presumably including MH-47D.

For shipboard operations, the MH-47E has the rotor brake of the civil Boeing 234. Boeing has demonstrated that the Chinook blades can be folded manually by four handlers in 40 min. For shipboard operations, both the MH-47E and MH-60K were designed to satisfy the 200 V/m EMI requirements of the US Navy.

The MH-47E has most of the same Aircraft Survivability Equipment as the MH-60K. The big Chinook still has no infrared suppressor but plans call for the Special Ops fleet to get the ALQ-211 Advanced Threat Infrared Countermeasures (ATIRCM) set around the year 2000.

The MH-47E has the structure needed for 0.50 caliber weapons in the port forward and starboard aft gunners' stations.

The last MH-47E was delivered to Fort Campbell in May 1995. One crashed in a storm in March 1996 and highlighted a tragic shortcoming in glass cockpits. Without a Flight Data Recorder (FDR), electronic flight instruments provide no clue to the cause of an accident. An accelerated effort put FDRs aboard the MH-47E and MH-60K and will eventually encompass the MH-47D and MH-60L.

The MH-47E and MH-60K gave the Night Stalkers the most advanced assault helicopters in the world. Digital maps and other systems improvements will upgrade the MH-47D and MH-60K to keep pace. A Little Bird replacement has long appeared in Army modernization plans. (The 800-kts AH-6 has difficulty keeping up with the 120-kts MH-60 and MH-47), and the Low Observable RAH-66 Comanche may someday have a SOF mission. Whatever the aircraft, the real power of the 160th Special Operations Aviation Regiment remains in its uniquely trained and highly dedicated people.

The 'glass cockpit' of the MH-60K has multifunction displays to show flight symbology, maps, and systems information. Many functions are automated to reduce workload in demanding missions. Center handle operates the FLIR turret. Conventional 'Boiler gauge' instruments in center panel are backups. (Allied Signal Guidance and Control Systems)
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The AHS Obscure History Maker
Can You Name It?
by John Schneider

In light of the growing emphasis at the Forum on Jet V/STOL (read Joint Strike Fighter) we decided the accompanying photograph would be appropriate. Can you name it and provide any other details — the designer, pilot, dates, size, power, weights, performance, and history of the project?
The winners and their answers will be printed in the next issue of Vertiflite magazine. The first person who faxes AHS National Headquarters will receive a copy of the popular tape “A Most Useful Invention: The Helicopter” and a women’s silk AHS scarf (which should make you popular at home). As always, we will award two winners, the first domestic and the first international respondents, since our overseas members are at a distinct delivery disadvantage. Fax or e-mail your information to Vertiflite Editor, AHS National Headquarters, 217 N. Washington St., Alexandria, VA 22314, USA; Fax (703) 739-9279; e-mail AHS703@aol.com.

Vol. 43, No. 2
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Rolling Along — The VSTOL Wheel
by Hal Andrews

Airlines or aeroplanes as they were in the earlier days of this century — have come in all sorts of shapes and sizes and they have been classified according to a variety of characteristics including speed, altitude and other performance capabilities. Helicopters, as they came into practical reality, similarly fell into convenient groupings sometimes differentiated based on the number of main rotors. Helicopter evolution generally followed the same track as that of airplanes but their development occurred over a much shorter period.

The concept that you could combine vertical takeoff and landing capability with airplane high speed was a compelling notion. Even before successful helicopters were flown, aeronautical inventors came up with “convertiplane” concepts to provide this advantage.

Word War II was the overall defining experience in this century of flight and it marked the beginning of modern flight with jet engines, helicopters and complex avionics. It is only appropriate to trace the “convertiplane” from these beginnings. Many VSTOL concepts subsequently evolved from this point and hence the appearance of the “VSTOL Wheel” which provides a useful classification guide for this category of aircraft.

Anything Was Possible

In the early post WWII years, anything was possible in the view of aeronautical practitioners. Even the downturn of military aircraft procurement and the collapse of the private airplane market (referred to as general aviation today) didn’t seem to blunt the enthusiasm of helicopter and airplane inventors and promoters.

As helicopters became more widely accepted, particularly in military operations, the inherent limits on their speed became increasingly obvious

"Perhaps the toughest question in the face of funding requests was, Why is this concept going to succeed when all the others didn’t?"

practitioners had been aware of how many years would go by before their ideas would become an operational reality, they might have had serious second thoughts. But the practicality of their early views has proved to be well founded. The tilt rotor, one of those initial hardware projects, is finally on its way to becoming the first operational aircraft in the original “convertiplane” category as the V-22. It is in the same designation series as the XV-3, one of the first three military convertiplane projects.

Haven’t We Tried That Before?

While the jet path led to earlier operational use of Harriers and only slightly later, the Soviet YAK-38’s, the long years of trying led to large numbers of concepts competing for supporting development resources. By the early 1960s, decision makers found it difficult to get understandable answers to many questions, starting with, “Haven’t we tried that before?” A more difficult question was, “Why is that vertiplane different from the last one we tried?” And perhaps the toughest question in the face of funding requests was, “Why is this concept going to succeed when all the others didn’t?”

The First Convertiplane Congress

In Philadelphia in December 1949, the First Convertiplane Congress was held. This event marks the ending for the initial post war activity and the initiation of more active VTOL development in the western world.

Spurred by increased military activity in support of the Korean War, rotor, propeller and jet concepts were all pursued in the U.S. resulting in the first flight hardware. If the early
quent decades the many concepts that were designed, ground tested in one way or another or actually were built and flight tested made their way onto the Wheel, appropriately classified by their different propulsion concepts. As aeronautics broadened into aerospace, some concepts that were hardly aeronautical but relied on its technology, were added in clearly denoted segments. Appropriate coding indicated the status reached by each project as the Wheel was updated.

With a STOVL version included in both of its demonstrator strike fighter multimission design families, the Joint Strike Fighter (JSF) Program found itself answering those same questions that prior VSTOL programs had addressed. Pulling out the Wheel, by now wholly overloaded, the JSF staff noted their program to initially build two pairs of X aircraft, each with a STOVL version, would allow a more directly related, easier to understand Wheel. Only those VSTOLs that had reached the stage of getting off the ground would be included. And it would still include the many missions for which VSTOL aircraft had been designed and the range of concepts. The fruits of all this effort, the "V/STOL Wheel of Misfortune" you can find on the next two subsequent pages.

The author would like to acknowledge the assistance of the Defense Group, Inc. and Sam Wilson of the NASA/JSF Program Office in the preparation of this article and the accompanying Wheel.

Vertiflite would also like to acknowledge the prodigious efforts of Mike Hirschberg of Anser Corp. in making this article and the accompanying artwork into a printed reality. Stay tuned for the May/June issue of Vertiflite where Sam Wilson, NASA Liaison to the JSF Program will articulate why the JSF Program will succeed where others before have failed.
V/STOL: The First Half-Century

by Michael J. Hirschberg, ANSER

Fifty years ago, the first ground tests were conducted for what would become a long heritage of Vertical and Short Take-Off and Landing (V/STOL) aircraft. Since then, 43 different types have been built and tested. The wheel of V/STOL Aircraft and Propulsion Concepts shows all the different methods that have been tried to combine the vertical flight ability of the helicopter with a high forward speed of fixed wing aircraft. Of all these attempts, so far only three aircraft, the Harrier, the Forger, and the Osprey, have been developed for operational service; only the Harrier is operational today, with the Osprey due to enter service in 2000. The Joint Strike Fighter (JSF) Program, however, is now developing two V/STOL aircraft which will demonstrate their propulsion concepts in 2000; one of these concepts will be selected for development as an operational aircraft to replace the Harrier in the next century.

Same Propulsion System for Hover and Forward Flight

This class of aircraft uses a single propulsion system that alters the direction of thrust for hover or cruise, or alters the attitude of the aircraft itself. Aircraft 9-14 rotated their powerplants, whereas all other aircraft in this wheel kept their engines stationary (except #30, the VJ 101C, which rotated four of its six engines).

Tilt Shaft/Rotor

These aircraft are convertiplanes using rotating blades that function like rotors in vertical flight and like propellers in forward flight. The rotors are long articulated blades which have cyclic pitch control for hover. The powerplants remain stationary with the power shaft pivoting from vertical to horizontal.

1. Transcendental Model 1G

The Transcendental Aircraft Company was formed by former Piazecki workers in 1945 to investigate tilt rotor technology. It built the single-seat open cockpit Model 1G in 1951. The 1G suffered from dynamic stability problems that were determined to be fundamental to the tilting rotor concept, so the Air Force funded research on rotors in transition including gyroscoptic effects and oblique airflow. The 1G then made its first flight (as a helicopter) on 6 July 1954 and made its first conversion to horizontal flight that December. A single 160 hp Lycoming O-290-A engine powered three-bladed 17 ft rotors at each wingtip. The piston engine had a manual two-speed reduction box that powered shafts down each wing. At the pivot, three concentric shafts supplied input to the rotors for tilt angle, cyclic pitch, and collective pitch. At the maximum engine speed of 3,000 rpm, rotor speed for hover was 240 rpm, while for horizontal flight they rotated at 633 rpm. The rotors required three minutes to transition through 82° of tilt during conversion, including the gear change. The 1,750 lb (fully loaded) 1G had a 26 ft long fuselage and a wingspan of 21 ft. The height was only 7 ft; in fact, the 1G was so small, the pilot’s head rose above the windscreen (see photo). The 1G flew over 100 flights and 20 hours before being lost in an accident on 20 July 1955 due to a rotor control mechanical failure. Top speed was about 160 mph. A 4,000 lb Model 2, with a 250 hp engine was tested in 1956-57, but the Air Force decided not fund it further in order to pursue the competing Bell XV-3.

2. Bell XV-3

One of the founders of Transcendental left to take the lead on the design of the Bell XV-3, which began under a joint Army-Air Force program in 1951. The XV-3 used the reliable 450 hp Pratt & Whitney R-985 radial engine mated to a two-speed manual gearbox, similar in principal to that of the Transcendental 1G. The fuselage was 30 ft long and had a 31 ft wing span. It made its first flight as a helicopter in August 1955, but crashed two months later before completing a full conversion. Extensive wind tunnel and rig tests were conducted after this, with pilots practicing the conversion process and gear changes (which required significant manipulation of the pitch and throttle controls and took about 20 seconds) in the tunnel. Rotor instability concerns led to a change from 23 ft three-bladed full-articulated rotors to 24 ft two-bladed semi-rigid rotors. The second XV-3 made its first flight on 12 December 1958 with a full conversion only 6 days later. Conversions over the
full 90° could be conducted in 10 seconds. Inadequate power and high weight growth precluded the XV-3 from hovering out of ground effect. The XV-3 made 110 full conversions and over 250 flights before it was damaged in a wind tunnel test in 1965 when a rotor housing separated from the aircraft. The ejection seats were thankfully never needed: they ejected downward.

**Tilt Prop**

This is basically the same as the tilt shaft/rotor concept, but with propellers instead of rotors. A propeller, with collective but no cyclic pitch control, has short, rigid blades with a high degree of twist.

3. **Curtiss-Wright X-100**

The X-100 was built primarily to flight test Curtiss-Wright's concept of using propeller "radial force" instead of wing lift for conventional flight. This phenomenon produces a large force at right angles to the airflow as the propeller angle of attack is increased. The X-100 used a 860 bhp fuselage-mounted Lycoming YT53-L-1 driving cross-shafts for the 10 ft diameter tilting fiberglass propellers at the wingtips. At the rear of its 24 ft fuselage, engine exhaust was used for pitch and yaw control in hover; roll control was provided by differential propeller pitch. Wingspan was 16 ft and gross weight was 3,500 lb. The X-100 first hovered in free flight in September 1959, and made its first short takeoff and landing flight on March 1960. Its first (and only) transition from vertical to horizontal was performed in April 1960. Control in hover was weak due to the low exhaust gas velocity. Testing continued until October 1961, sufficiently proving the Tilt Prop concept to the extent necessary to proceed with what would become the X-19.

4. **Curtiss-Wright X-19**

Using the radial force lift concept proven by the X-100, Curtiss-Wright designed a six passenger civil executive transport, originally designated the X-200. As part of the Army/Navy/Air Force Tri-Service Assault Transport Program, the Air Force contracted for conversion of two prototypes, designated X-19, extensively modified for military requirements with ejection seats, rescue hoist, mock refueling probe and a fuselage stretch for improved passenger access. The 44 ft long aircraft was powered by two Lycoming T55-L-7 turboshaft engines producing 2,650 shp each. At the end of each tandem wing was a 13 ft three-bladed wide chord, high twist propeller. In order to eliminate gyroscopic and torque effects, propellers located diagonally rotated in the same direction. Roll, pitch and yaw were all controlled by differential propeller pitch. Empty weight as flown reached 10,000 lb, and gross weight over 12,000 lb. The first aircraft hovered on 20 November 1963, but suffered a hard landing. It was repaired, but problems with the control system and a series of mechanical problems plagued the program. On 25 August 1965 a transmission part failure caused an asymmetric lift situation, which allowed the crew to validate the operation of their ejection seats. When the program was canceled four months later, the first aircraft had made 50 flights, but for a total of only four hours. The second aircraft was never flown.
Tilt Ducts

Putting a propeller inside a duct can produce as great as a 50% thrust increase due to the Bernoulli Effect, and also provide additional lift in forward flight. Propeller pitch as well as deflector vanes in the downwash can control the aircraft in hover and transition.

5. Doak 16 VZ-4

The Doak 16, which received the Army designation VZ-4, was built in 1957. It was 32 ft long, had a gross weight of 3,200 lb, a tandem two-seat cockpit, and a 16 ft wingspan. Each wing ended in eight-bladed 4 ft wide propellers within tilting ducts; they were powered by a single 860 bhp Lycoming YT53 engine. The first flight was made on 25 February 1958. Transition from hover to 200 kt could be made in less than 20 seconds. Variable inlet guide vanes controlled roll in hover, and engine exhaust gases were deflected at the rear of the fuselage for pitch and yaw control. Deceleration and descent had to be carefully controlled in order to prevent the lip of the duct from stalling, as well as to manage a large upward pitching moment from the ducts acting as a wing at a high angle of attack. The Doak 16 suffered from a lack of control power, but completed over 50 hours of testing and proved the feasibility of the tilt duct concept.

6. Bell X-22A

The X-22A was the Navy contracted and managed portion of the Tri-Service Assault Transport Program. The Bell X-22A was 39 ft long, featured side-by-side pilot seats, and had a gross weight of 17,000, including six passengers or a 1,200 lb payload. It was powered by four 1,250 shp GE YT58-GE-8D turboshift engines that were cross-linked and had 85% excess power in case one of the engines failed in hover. Span over the canard (including the 7 ft diameter three-bladed ducted propellers) was 23 ft; across the rear wingtip ducts it was 39 ft. The ducts rotated non-differentially from 0° to 95° and had spanwise elevons across the center of the duct. Differential propeller pitch and the elevons were used to control the X-22A in hover. In forward flight, the ducts provided a significant amount of the aerodynamic lift. The first aircraft was rolled out on 25 May 1965. It made its first hovering flight in March 1966, and was tested to transition angles of up to 30° at speeds of up to 100 kt. That August, the first prototype was lost in a hard landing after only three hours of flying time due to a hydraulic failure. The second prototype made its first flight in January 1967 and performed hundreds of complete transitions. It reached a maximum speed in forward flight of 315 mph, and had a range of 450 miles. In early 1968, the X-22A's variable stability and control system was demonstrated, which allowed for research into hover and transition flight characteristics of other possible V/STOL aircraft. On 30 July 1968, it set a record by hovering at an altitude of over 8,000 ft. Flying until 1980, it accrued about 200 hours in the air.

7. Nord 500 Cadet

In 1966, the French company Nord (later part of Aérospatiale) built two Cadets, each powered by two 317 shp Allison T63-A-5A engines. The Nord 500 Cadet was 22 ft long and 20 ft wide, weighed only 2,760 lb and used two
relatively large five-bladed ducted propellers. On the exit end of the ducts, four control vanes in a diamond shape controlled pitch (collectively) and yaw (differentially). This configuration was selected to try to expand the airflow in hover and compress it during horizontal flight. The first aircraft was used for static tests while the second made a tethered hover on 23 July 1968. It was canceled without being tested further.

### Tilt Wing

Tilting the entire wing, instead of just the rotor or propeller, provides the benefit of increasing aerodynamic flow over the lifting and control surfaces during transition, and minimizes the lift loss due to downwash in hover. Disadvantages, however, are that an additional method of control such as a tail jet or rotor is required for control in hover, and ailerons change from roll control in horizontal flight to yaw control in hover. Control is especially difficult in hover during gusts due to the "barn door effect" of the wings in a vertical position.

#### 8. Vertol 76 VZ-2

The Vertol 76 received the Army designation VZ-2 in early 1956. The 26.5 ft fuselage was built of metal tube construction, and had a helicopter-like two seat cockpit. A single 860 bhp Lycoming YT53-L-1 was mounted on the fuselage, and drove the two 9.5 ft three-bladed propellers by a cross-shaft through the 25 ft span wings. In hover, pitch and yaw were controlled by two ducted propellers in the tail; in transition, aerodynamic controls were phased in until the tail propellers were no longer needed in horizontal flight. Ground testing began in April 1957. The first vertical flight was made on 13 August 1957, first horizontal flight on 7 January 1958, and first complete transition on 15 July 1958. It continued to fly until 1965, making over 450 flights, including 34 full conversions.

### 9. Hiller X-18

The Hiller X-18, begun in February 1957, used various components from existing aircraft. The fuselage was that of a Chase YC-12C transport. The two wing-mounted 7,100 shp Allison T40-A-14 turboshifts came from the XFY-1/

[Image of Hiller X-18]

Hiller X-18

The XFV-1 tail sitter (#23 and #24) program and could not be cross-linked. It had three engines, the two turboprops drove the 16 ft diameter counter-rotating three-bladed propellers and a 3,400 lb thrust Westinghouse J34 turbojet which produced pitch control thrust. The 33,000 lb loaded X-18 underwent extensive ground tests beginning in December 1958, and made its first conventional flight on 24 November 1959. It made partial conversions with wing angles of up to 33° (relative to the fuselage) — with a 17° nose-up attitude, the wings had an effective 50° degrees of tilt (relative to the flight path). The turboprop engines had electric pitch controls and were too slow to provide adequate response in hover. On the 20th flight it had a propeller pitch control problem at 10,000 ft and went into a spin. It was recovered before impact, but was grounded, having never achieved hover. It continued to test ground effects before it was damaged by a test stand failure.

### 10. LTV-Hiller-Ryan XC-142

The XC-142 aircraft was the third aircraft evaluated in the Tri-Service Assault Transport Program. It used four cross-linked 3,080 shp General Electric T64-GE-1 engines, each driving a 15.5 ft four-bladed propeller. Roll was controlled by differential propeller pitch, and pitch by an 8 ft three-bladed variable pitch tail rotor. Yaw was provided by ailerons powered by propeller slipstream. The wing could tilt through 100° allowing the XC-142 to hover in a tailwind. The tail rotor folded to the port side to reduce the stowage length and to protect against accidental damage during loading. This cargo aircraft was 58 ft long, had a wingspan of 67 ft and was capable of transporting 32 troops and gear or 8,000 lb of cargo. It had a rear loading ramp and had a maximum gross weight of 41,000 lb for a vertical take-off, or 45,000 lb for a short take-off. It made its first conventional flight on 29 September 1964, first hover on 29 December 1964, and first transition on 11 January 1965. Air Force trials included cargo flights, cargo and paratrooper drops, and desert, mountain, rescue, and carrier operations. Five aircraft were
built, but mechanical failures (primarily the cross-shaft and gear boxes which could be damaged during wing flexing) and operator error caused four of them to be damaged in hard landings. One crash occurred as a result of a failure of the drive shaft to the tail rotor, causing three fatalities. The XC-142 suffered from excessive vibration and noise, resulting in a high pilot workload. During the program, the XC-142 accrued 420 hours by 39 different pilots as an operational evaluation aircraft.

11. Canadair CL-84 Dynavert

The Canadian CL-84, begun in November 1963, was a quarter the size of the XC-142. It weighed 8,100 lb empty, could make a vertical take-off at 12,200 lb, or a short take-off at 14,700 lb. The wings were 33 ft long and housed two 1,450 shp Lycoming T53-LTC1K-4A turboprops which powered the cross-linked 14 ft four-bladed propellers. Pitch control was provided by two counter-rotating two-bladed horizontal propellers, which in horizontal flight were stopped and aligned to minimize drag. Roll control was by differential pitch, and yaw was controlled with ailerons. It made its first vertical flight in May 1965, and first conventional flight that December. A total of four aircraft were built, including one which was not flown. US pilots evaluated it extensively, including demonstrations on amphibious ships and the Pentagon helipad. Neither government was sufficiently interested to order production aircraft. Two aircraft were destroyed in non-fatal accidents due to mechanical failures.

**Tilt Rotor**

The aircraft tilted the rotors for transition from vertical to horizontal flight. Like the larger Tilt Wings (nos. 9-11), the engines tilted together with the rotors.

12. Bell XV-15

Over twenty years after they began work on the XV-3, Bell received a contract to begin work on their 13,000 lb Research Tilt Rotor aircraft, which was designated XV-15. The 42 ft fuselage housed side-by-side pilot seats. At each tip of the 35 ft span wings, a 1,550 shp Lycoming T53-LTC1K-4K turboshaft engine powered a 25 ft diameter three-bladed rotor. The engines and rotors tilted through 90° and were cross-linked in the event of engine failure. The rotors were semi-rigid stainless steel with a high twist and no flapping hinges. Control at low speeds was by cyclic and collective blade angle adjustments. The first hover of the joint Army/NASA XV-15 was performed on 3 May 1977. The first aircraft was later tested extensively in the wind tunnel. Aircraft number two made its first hover on 28 April 1979. It made the first conversion to horizontal flight on 24 July 1979. In the next several years, the XV-15 conducted extensive tests, shipboard landings, and achieved a maximum speed (in a dive) of 397 mph. By 1986, it had made 1,500 conversions in 530 flight hours. The aircraft was flight tested aboard the USS Wasp in 1990 to evaluate shipboard compatibility issues of the tilt rotor concept.

13. Bell Boeing V-22 Osprey

In 1983, Bell, teamed with Boeing Vertol, was selected to develop their Tilt Rotor concept into the Army/Navy/Marine Corps/Air Force V-22. It is powered by two Allison
T406-AD-400 engines which drive 38 ft three-blade rotors on a 45 ft wingspan. The cross-shafted engines are each rated at 6,150 shp for take-off with the maximum continuous rating of 5,890 shp; the transmission is rated at less than 5,000 shp for normal operations, but nearly 6,000 shp for emergencies. The Osprey made its first flight on 19 March 1989 and first transition on 14 September 1989. It is capable of transporting 24 troops or 864 cubic feet of cargo. A loading ramp is in the tail of the 57 ft fuselage. Normal vertical take-off weight is 47,500 lb, while maximum gross weight for a short take-off and landing can be as high as 60,000 lb, including up to 20,000 lb of internal or external payload. Combat range is about 600 miles, while maximum ferry range is 2,400 miles. Maximum speed is nearly 400 mph. By the end of 1996, over 1,100 hrs of flight testing had been conducted with five development aircraft; two aircraft crashed (1991 and 1992) the latter one killing seven people. The first of four “production representative” test aircraft began flying on 5 February 1997. A total of 523 aircraft will now be built for the Marine Corps, Navy, and Air Force, with the first V-22s becoming operational in 2000.

Tilt Jet

Like the Tilt Rotor, the Tilt Jet rotates the entire propulsion system from the vertical for hover to the horizontal for conventional flight, but uses a jet engine.

14. Bell 65 Air Test Vehicle (ATV)

In 1954, Bell built their Model 65 Air Test Vehicle (ATV) of parts from a number of commercial aircraft. A 1,000 lb thrust Fairchild J-44 missile turbojet engine mounted on each side of the aircraft under the wing could be tilted from vertical to horizontal. A Turbomeca Palouste turbocharger provided reaction jets at the tail and wingtips for control in hover. It made its first hover on 16 November 1954 from a platform to prevent the ATV from reingesting its exhaust gases. The ATV was modified with a wheeled landing gear and made horizontal flights in 1955. It made partial conversions at altitude, but had inadequate engine thrust to complete the transition. Bell ended the program in 1955 in favor of its X-14 (#18), but used this tilt jet experience to develop the Air Force XF-109 V/STOL fighter concept; although canceled before being built, this concept was very similar to the later VJ 101C (#30).

Deflected Slipstream

Deflecting propeller slipstream 90° downward with the trailing flaps forms a “bucket” that can vector propeller thrust vertically.

15. Robertson VTOL

Robertson Aircraft Corporation was formed in October 1956 to build a four seat vertical take-off and landing (VTOL) aircraft powered by two supercharged 340 hp Lycoming GSO-480 engines. The wing had a sliding flap system with a double-slotted full span trailing edge flap providing all control. The flaps were retracted into the low aspect ratio wing for horizontal flight. All fuel and oil were carried in wing tip tanks which also acted as endplates. This capped the wing “buckets” and should have improved cruise efficiency. The aircraft made a tethered flight on 8 January 1957 but was not pursued.
16. Ryan 92 VZ-3 Vertiplane

The Ryan 92, designated VZ-3 by the Army in June 1956, was intended to be a reconnaissance and liaison aircraft able to operate from unprepared surfaces. It had a 28 ft metal fuselage and was powered by a 1,000 hp Lycoming T53-L1 turboshaft engine driving a metal three-blade Harzellel propeller on each side. The propellers were situated ahead of and below the wing, so the majority of the propeller slipstream flowed directly into the bucket formed by the extended double flaps and were turned downward for vertical lift. Differential propeller pitch was used for roll control.

Engine exhaust was used at the tail for pitch and yaw before aerodynamic controls were effective. Ryan began taxiing trials on 7 February 1958. After extensive wind tunnel tests and aircraft modifications the first flight was made on 21 January 1959. The engines were unable to provide sufficient power to hover without a head wind. An accident the next month grounded it for repairs until its first test by NASA in February 1960; unfortunately the pilot ejected after an unplanned maneuver. It was again rebuilt for flying status: modifications after the crash led to a fabric nose section, an open cockpit, and a different landing gear. It continued flying in 1961, testing low-speed V/STOL handling characteristics.

17. Fairchild 224 VZ-5 Fledgling

The Fairchild M-224-1 Fledgling was powered by a 1,024 hp General Electric YT58-GE-2 turboshaft engine turning four three-bladed Harzellel metal propellers. The open cockpit had room for the pilot as well as a jump seat. The aircraft could either sit on its forward tricycle landing gear or rest on its two main wheels and a tail skid, providing the Fledgling with 30° of inherent rotation to enhance the “bucket’s” effectiveness. Small rotors at the top of the T-tail controlled pitch during hover. Tethered tests were made in late 1959, but it never flew.

**Vectored Thrust**

This class vectors the exhaust of the jet engine to create vertical or horizontal motion.

18. Bell X-14

Built under a US Air Force contract, the X-14 used a planar array of diverter vanes to vector the exhaust of two Armstrong Siddeley ASV8 Viper engines (1,750 lb thrust each) at the center of gravity (c.g.). The vanes could be rotated to direct the exhaust from vertical to nearly horizontal. The 25 ft fuselage and tail were from a Beech T-34; the 34 ft span wing was from a Beech Bonanza. The lack of an ejection seat limited hover testing to very low and very high altitudes. The gross weight was originally only 3,100 lb. The landing gear had to be lengthened when the phenomenon of suck-down was first discovered. Engine gyroscopic effects and exhaust gas reingestion were also encountered. First hover flight was achieved on 17 February 1957; first transition was made on 24 May 1958. The Viper engines were replaced with higher power GE J85 engines when it was transferred to NASA in 1960. It was eventually fitted with a digital fly-by-wire control system and continued flying as a V/STOL testbed until 1981!

19. Hawker P.1127 Kestrel

The Hawker/Bristol funded P.1127 development began in 1957. The Bristol Pegasus engine (originally with only
Hawker P.1127 Kestrel

11,000 lb thrust was developed for the aircraft with heavy US funding support. It was based on the earlier Orpheus engine, and had a bifurcated jetpipe and vectoring front and rear nozzles. The P.1127 made its first hover on 21 October 1960 on tethers, but this was not considered to be beneficial to feel the aircraft response, so the first untethered hover was made less than a month later, on 19 November 1960. First conventional flight was made on 7 July 1961 and first double transition on 12 September 1961. Control power was low about all axes, which, combined with suck-down and limited height control power, resulted in a high pilot workload in hover. Hot gas ingestion was overcome with a low forward speed in takeoff and landing. One of the two initial test aircraft crashed, with the pilot ejecting safely. The British government began supporting the development before the first flight, funding the first two prototypes, and later four more. Pegasus 3 power was increased to 13,500 lb thrust. In 1962, the UK, US and Germany initiated a tripartite program, funding nine improved P.1127 Kestrels for use by a UK-led tri-national squadron which conducted operational trials. These used Pegasus 5 engines, with thrust increased to 15,500 lb. The Kestrel paved the way for the Harrier (#21).

20. Yakovlev Yak-36 Freehand

The Freehand was powered by two non-afterburning Soyuze Tumanskiy/Khatchaturov R-27-300 turbojet engines (11,000 lb thrust each) mounted forward of and below the cockpit. They were fitted with louvered nozzles, which were vectorable through about 90° and exhausted at the center of gravity (c.g.), similar to the Bell X-14 (#18). Engine bleed air was used for reaction control nozzles at the tip of each wingtip fairing, on the tailcone, and at the tip of a ten foot long nose “probe.” The overall length was 57.5 ft long (including the nose probe), with a wingspan of 27 ft. Empty weight was 12,346 lb, maximum take-off weight was 20,723 lb. The Yak-36 made its first untethered hover on 9 January 1963. From there, the flight envelope was slowly expanded, with a double transition from vertical take-off to forward flight and back to vertical landing performed on 16 September 1963. A number of retractable doors (including a large “apron” under the nose) were fitted to reduce hot gas ingestion. It was only capable of vertical take-offs and landings. The first public display was at the Soviet National Aviation day on 7 July 1967 at the Domodedovo Air Show. The Yak-36 was a technology demonstrator that eventually led to the operational Yak-38 Forger.

21. McDonnell Douglas/British Aerospace Harrier

Following the Hawker (later British Aerospace) Kestrel operational trials (#19), the first of six production-designed Harrier developmental aircraft flew on 31 August 1966. The production GR1 Harrier entered service with the UK Royal Air Force on 1 April 1969 powered by the 19,000 lb Bristol (later Rolls-Royce) Pegasus Mk 101. US Marine Corps AV-8As were purchased in 1969, powered by the 21,500 lb
thrust Pegasus 11. A navalized version, the FRSI Sea Harrier, entered service with the Royal Navy in 1980. McDonnell Douglas (later with British Aerospace) began developing the AV-8B GR5 Harrier II in 1974, and began flight testing in 1981. With a more powerful engine, a larger, composite supercritical wing, optimized Lift Improvement Devices (LIDs) and other improvements, the Harrier II was able to double the payload and range when making short takeoffs. The F402-RR-408 Pegasus 11-61 has now reached 23,800 lb thrust. Today, the Harrier is the only operational V/STOVL aircraft in the world. In addition to the USMC, the UK RAF and RN, the Harrier is also operated by Spain, Italy, India and Thailand.

22. Boeing X-32

As part of the Joint Strike Fighter (JSF) program, the Boeing X-32 concept demonstrator (artist’s drawing above) uses a derivative of the Pratt & Whitney F119 engine with Rolls-Royce lift components. The X-32 concept has a chin inlet and a blended delta wing. In short take-off and vertical landing (STOVL) mode, the engine closes the vectorable cruise nozzle and opens two lift nozzles at the aircraft e.g. First flight is planned for 2000. The winner of the JSF source selection in 2001 will then develop its operational STOVL version of the concept as a supersonic multirole aircraft to replace the Harrier. Boeing’s design for the operational aircraft has an empty weight of about 22,000 lb, length of 45 ft and a wingspan of 30 ft; maximum take-off weight would be about 50,000 lb. During the Concept Development Phase that ended in November 1996, Boeing completed 11,700 hours of developmental testing and piloted simulations, including testing of a Pratt & Whitney YF119-powered 94% scale model in 1995.

23. Lockheed XFV-1

An aircraft that points straight up permits the entire thrust of its propulsion system to be converted directly into vertical lift. Unfortunately, while it may be somewhat easy to take off facing up, it was considerably more difficult to land facing the opposite direction the aircraft was traveling.

Tail Sitters

After World War II, the US Navy was looking for ways to improve ship defense by equipping merchant ships with vertical take-off aircraft. A 1950 design competition selected Convair (#24) and Lockheed to each build a single-seat tail sitting fighter aircraft. Each used the Allison YT40-A-14 engine (two coupled T38 power sections mounted side-by-side) driving two 16 ft counter-rotating three-bladed Curtiss-Wright propellers with electric pitch control. The engines produced 5,500 eshp with a 7,100 eshp take-off rating, resulting in over 10,000 lb of thrust. The 37 ft fuselage had mid-mounted 30 ft span wings. Control in hover was by the same large aerodynamic surfaces as in level flight, as each was bathed in propeller slipstream; the “X”-shaped tail arrangement minimized downwash masking. An erecter trolley was used to stand the XFV-1 in the vertical position; the tips of each tail had a small castoring wheel. The aircraft was fitted with a temporary conventional attitude landing gear and made its first horizontal flight in March 1954. A total of 27 conventional flights were made, with the first full transitions made above 1,000 ft that Fall. Control in hover was very weak, and the pilot had difficulty in determining sink, climb, and rotation from normal visual cues. No vertical take-offs or landings were ever attempted.

As with the Convair XYF-1 Pogo, the engine and control systems were judged to be insufficient.

24. Convair XYF-1 Pogo

As with the Lockheed XFV-1, the Pogo used the Allison YT40-A-14 engine and Curtiss-Wright counter-rotating propellers, but was somewhat more compact and less conventional in appearance. The Pogo was 31 ft long with a 26 ft wide delta wing. A large vertical stabilizer above the wing was matched by an equally sized ventral fin below which
could be jettisoned for an emergency horizontal landing. The seat was inclined 45° toward the instrument panel for vertical flight. Control in hover for the XFY-1 were also the same as for conventional flight, but again this provided only limited control power. Almost 300 tethered tests hanging from the ceiling of Moffett Field’s airship hangar were made in April 1954. First free hover was on 1 August 1954. The first double transition to horizontal flight and back to a vertical landing was made on 2 November 1954. The Pogo was flown until November 1956. As with the Lockheed XVF-1, the engine and control systems were considered inadequate.

25. Ryan X-13 Vertijet

After remote controlled tethered rig tests from 1947 to 1950 and a flying rig in 1951, Ryan was awarded an Air Force contract in 1953 to develop an actual flying jet-powered VTOL aircraft, which was given the designation X-

13. It was only 24 ft long — just large enough to accommodate a cockpit (again with a tilted seat) and the 10,000 lb thrust Rolls-Royce Avon turbojet. Its high mounted delta wing had a wingspan of only 21 ft, capped with flat endplates. At the tip of the nose was a short pole ending in a hook. The hook was used to capture a wire on a vertical trailer bed. Once captured, the trailer was lowered to horizontal and could be transported on the ground. Engine thrust was vectored to provide pitch and yaw control in hover, while roll was provided by puffer jets outboard of the endplates. The first prototype was fitted with a temporary landing gear and made its first horizontal flight on 10 December 1955. It later made full conversions to vertical attitude and back at altitude. The landing gear was then replaced by a rear mounted castoring framework, known as the “roller skate” and hooking practice was conducted. The second prototype followed a similar progression; on 11 April 1957, it made a vertical take-off from the raised trailer, transitioned to horizontal flight and back, ending with hooking on the wire “trapeze.” On 28–29 July of that year, the X-13 was demonstrated in Washington, hovering across the river to the Pentagon. The Air Force chose not to continue development of the Vertijet because of the lack of an operational requirement.

26. SNECMA C450 Coléoptère

In France, the Société Nationale d’Etude et Construction de Moteurs d’Aviation (SNECMA) began working on a jet-powered tail-sitter in 1954. Various rigs were tested from 1955–1957 powered by the 6,400 lb thrust Atar D jet engine, each with increasing complexity. The C450 Coléoptère (“annular wing”) was the final step in the program. It had a 22 ft fuselage surrounded by a 10.5 ft diameter annular wing with four small fins above castoring wheels. The airframe was built by the Nord company. Control in hover was provided by tilting vanes in the nozzle of the 7,700 lb thrust Atar 101E turbojet. In forward flight the small fins deflected the air for control. Two small strakes in the nose could be extended to facilitate a pitch-up moment in tran-
V/STOL Aircraft and Propulsion Concepts

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Depicted here are the various types of Vertical and Short Take-Off and Landing (V/STOL) aircraft which have been tested over the past 40 years. All were built to be flown, but only three (shown in bold) have led to operational aircraft. In fact, the Harrier is the only V/STOL aircraft in service today.

The Joint Strike Fighter concept demonstrators (shown in blue), are scheduled to fly in 2000; one of these concepts will serve as the basis for development of an aircraft to replace the Harrier.
sition back to vertical. First tethered hover was on 17 April 1959; first free hover was on 3 May 1959, lasting for 3 minutes. The ninth flight was on 25 July 1959; it was to transition to about 36° from the vertical and then return to hover at 2,000 ft before beginning a vertical descent. However, the Coléoptère was unable to establish the hover and began descending faster than desired and fell into oscillations about all three axes. The pilot ejected at 150 ft but was badly hurt. The Coléoptère rotated to about 50° and accelerated horizontally, but did not quite complete the transition and crashed. Emphasis on both sides of the Atlantic changed from dispersal to air superiority and attack, roles for which the tail sitters, with their small payload and range, were ill-suited.

Separate Power Plant for Hover
This class of aircraft used two separate groups of power plants: one for hover, and one for cruise.

Lift + Cruise
These aircraft use lift engines for hover only, and separate engines for cruise only. A lift engine is a vertically mounted jet engine that is highly optimized to produce a relatively large amount of thrust for the short duration of take-off and landing.

27. Short SC.1

Work began in 1954 to design a test aircraft that could demonstrate the utility of the recently developed Rolls-Royce RB.108 lift engine, producing 2,130 lb thrust each (a thrust to weight of 8.1). The Short Brothers SC.1 was powered by four RB.108 lift engines vertically mounted on gimbals in the center fuselage and one RB.108 cruise engine in the rear for forward flight. Ground carts were used to spin the lift engines up to speed for take-off; for landing, cruise engine bleed air was used. The SC.1 was designed to study hover, transition and low-speed flight, and had a fixed landing gear. Gross weight was 7,700 lb, with a total vertical thrust 8,600 lb. Overall length was 30 ft; the wingspan was 23.5 ft. Bleeds from the four lift engines powered nose, tail, and wing tip reaction jets for control at low speeds. First CTOL flight was made on 2 April 1957; first tethered vertical flight was on 26 May 1958, first free vertical flight was on 25 October 1958; first transition was on 6 April 1960. The SC.1 experienced the typical suck-down and hot-gas ingestion problems discovered during V/STOL development programs. It appeared at the Farnborough air show in 1960 and Paris air show in 1961 (for the latter it flew the English Channel both ways). Maximum speed was only about 250 mph due to the low thrust of the single cruise engine. Pilot workload was very high during landing, just when pilot attention was most important. The lift engines had to be started as late as possible, due to the high combined fuel consumption of the five engines. The ignition procedure was very labor intensive, as was transition from wing-borne to jet-borne flight. The second test aircraft crashed on 2 October 1963 due to a controls malfunction, killing the pilot. It was rebuilt and the two aircraft continued to fly until 1967.

28. Dassault Balzac V

Although there was no British requirement for the RB.108 lift engine, Dassault in France was interested in developing a supersonic vertical take-off and landing fighter. The first step was to take eight of the existing RB.108 lift engines and install them in the Mirage III prototype airframe 001. The rebuilt aircraft, nicknamed Balzac, weighed about 13,500 lbs. It had a fattened and stretched fuselage (43 ft), but the same 24 ft span wings. The inlet duct for the cruise engine, the 4,850 lb thrust Bristol Orpheus, ran down the center of the lift engine collection. The front four engines were also separated from their rear counterparts by the main landing gear to balance the center of gravity. Each lift engine pair shared an inlet door and an exhaust door. First tethered hover was performed on 12 October 1962, with the first free hover made 6 days later. First conventional flight was made.
on 1 March 1963. During transition, all the lift engine doors created quite a bit of drag. On 27 January 1964, during one of the first transition attempts, it crashed in a “falling leaf” accident, killing the pilot. It was rebuilt and killed another pilot on 8 September 1965; this time it was beyond repair.

29. Dassault Mirage III-V

The III-V (V for “vertical”) was a Mirage III airframe, modified with eight RB.162-31 lift engines (generating 5,400 lb thrust each, or 16:1 thrust to weight!), long-stroke landing gears, and various doors to minimize the undesirable effects of the lift engine exhausts. It was 59 ft long, with a 29 ft wingspan, and weighed about 30,000 lb. It was powered by a SNECMA TF-104 (12,000 lb thrust dry, 20,000 lb in afterburner). Control power was improved over the Balzac, with similarly located control jets at the nose, tail and wingtips. First hover was achieved on 12 February 1965. The TF-104 was upgraded to a TF-106 for the first supersonic flight. First transition was conducted in March 1966. The second aircraft was fitted with a 10,750 lb thrust Pratt & Whitney TF30. It is the fastest V/STOL aircraft on record, achieving Mach 2.04 on 12 September 1966. The eight engines didn’t leave much room for fuel and a visiting US Air Force pilot had to eject, destroying one of the two aircraft when he ran out of fuel during low-speed and hover operations. The other III-V was also lost. With the entire fuselage filled with lift engines, the Balzac and the III-V seemed to prove that with enough lift engines, any aircraft could be converted to V/STOL. The problem, however, was that there was no room for anything else. The Mirage III-V weighed about 3,000 lb over the basic Mirage III, which cost about half the payload and fuel.

Combined Power Plant for Hover

This class of aircraft used its main propulsion system for both hover and cruise, but also had a separate propulsion system for additional hover thrust.

Lift + Lift/Cruise

One set of lift engines for lift only, and another set of engines for both lift and cruise.

30. EWR VJ101C

The supersonic VJ 101C, built by the German EWR (“Consortium”) of Messerschmitt, Heinkel and Bolkow, employed a lift plus lift/cruise propulsion concept, powered by six Rolls-Royce/MTU RB.145 turbojet engines. Two of these engines were mounted in tandem aft of the cockpit; the other four engines were in pairs in wingtip swivelling nacelles. On the second of the two experimental aircraft, the VJ 101C X2, the wingtip mounted engines were equipped with afterburners which increased their available thrust from 2,750 to 3,650 pounds each. The first VJ 101C hovering flight occurred on 10 April 1963, and the first horizontal takeoff was accomplished on 31 August 1963. A double transition (vertical takeoff through conventional flight followed by a vertical landing) was achieved on the sixth flight on 20 September 1963. The non-afterburning X1 became the world’s first supersonic V/STOL aircraft in July 1964 when it broke the sound barrier in a shallow dive. This aircraft was lost in an accident on 14 September 1964. This occurred when the aircraft became uncontrollable immediately after a horizontal takeoff. The pilot ejected at an altitude of ten feet during an uncommanded roll. He survived but suffered crushed vertebrae. The accident was found to have been caused by a roll-rate gyro which had been installed with reversed polarity. Prior to its loss, the VJ 101C X1 had completed 40 aerodynamic flights, 14 full transition flights and the Hannover Air Show presentation on 3 May 1964. The VJ 101C X2 flew its first hovering free flights on 12 June but did not attempt to use its afterburning capabilities for vertical takeoffs until 10 October 1964; within two weeks, the VJ 101C X2 demonstrated complete transitions from vertical to horizontal flight and back to a vertical landing using afterburning. It suffered from high temperature and erosion issues, and crashed when it ingested hot exhaust gases and suffered a significant thrust loss.
while attempting to land on an elevated platform. The rotating nacelle design was abandoned, and the proposed follow-on, the VJ 101D, dispensed with the wingtip-mounted engines but retained the lift plus lift/cruise propulsion concept. Its use of RB.162 five lift engines and two aft fuselage RB.153 lift/cruise engines (with internal thrust deflectors) was very complex and the VJ 101D was canceled after engine testing had begun.

31. Dornier Do 31

The German Dornier Do 31 project was begun in the early 1960s as a 50,000 lb gross weight vertical take-off and landing military transport plane, capable of lifting 6,000-8,000 lb. It was 68 ft long, with a two pilot crew sitting side by side. It could load 1,470 cubic ft of cargo through the rear loading ramp. It used two 15,500 lb thrust Bristol Pegasus 5-2 engines and eight 4,400 lb thrust Rolls-Royce RB.162-4D engines. The powerplants were divided into four wing-mounted pods – a Pegasus pod and a pod of four lift engines on either side of the fuselage. The lift engine pods were located at the ends of the 59 ft span wing. The lift engine exhaust could be vectored backward or forward 15° for take-off and landing, respectively. The Pegasus could vector exhaust from 30° forward to 80° back. Differential vectoring and thrust levels were used for control in roll and yaw; pitch was affected by a puffer jet in the tail. After almost four years of hover rig tests of increasing size and realism to develop the autostabilization controls, three Do 31 aircraft were built: one each for conventional flight trials, ground testing, and hover and transition research. The first aircraft made a conventional flight without the lift engine pods on 10 February 1967. The third aircraft made the first hover on 22 November 1967. First transition from vertical was on 16 December, and first transition to vertical 6 days later. It continued to fly until it was canceled in April 1970: the large drag and weight of the engine pods reduced the useful payload and range compared to contemporary conventional transports.

32. Lockheed XV-4B Hummingbird II

In 1964, when the XV-4A (#38) proved unsatisfactory, the remaining Hummingbird was modified with four General Electric J85-GE-19 lift engines (3,000 lb thrust) for hover. Two additional J85 engines provided thrust during horizontal flight. During hover, large diverter valves directed the cruise engine exhaust on each side through the fuselage to a nozzle between the lift engines for additional vertical thrust. In transition, one lift/cruise engine was diverted, while the other provided forward thrust. Pitch and yaw jets at the nose and tail provided control in hover. Maximum vertical take-off weight was 12,600 lb. The Hummingbird II had a fly-by-wire dual channel autostabilization system. It was rolled out on 4 June 1968 but was destroyed in a crash during a conventional flight on 14 March 1969, without ever making a hover.

33. VFW VAK 191B

The VAK 191B used two Rolls-Royce/MTU RB.162-8D lift engines (6,000 lb thrust each), one mounted directly behind the cockpit and one aft of the wing, plus a MTU/163-12 vectored thrust turbofan engine (10,163 lb thrust) mounted between them. The RB.193 was a scaled down version of the Roll Royce Pegasus engine used.
on the Kestrel/Harrier. First untethered hovering flight of the German/Italian VAK 191B was conducted on 10 September 1971, with first transition achieved on 26 October 1972. The program was intended to develop a high-speed V/STOL strike aircraft; but it was canceled due to a change in NATO strategy. The US Navy subsequently funded additional V/STOL oriented flight tests.

34. Yakovlev Yak-38 Forger

The Yak-38 Forger used two in-line Rybinsk RD-36-35FVR lift engines (6,722 lb thrust each) immediately behind the cockpit inclined with the engine exhaust at 13 rearward. One Soyuz Tunanskiy/Khachaturov R-27V-300 turbojet (13,444 lb thrust) was mounted in the center fuselage and exhausted through two hydraulically actuated vectoring nozzles (connected by a transverse shaft), one on each side of the fuselage just aft of the trailing edge of the wing. The first prototype flew in 1971 and the Yak-38 (originally designated the Yak-36M) first appeared to the West in July 1976 when the Kiev deployed with a developmental squadron of Forger-As and traveled through the Mediterranean. The normal complement for the Kiev-class through deck aircraft carrier was a dozen single-seat Forger-As and one or two twin-seat trainer Yak-38U Forger-Bs. The primary roles were fleet defense (particularly against shadowing maritime surveillance aircraft), reconnaissance, and anti-ship strike, but was never used in combat. The Forger was removed from front line service in 1992-93, although a few remained in the inventory for another year as limited proficiency training aircraft. A total of 251 aircraft had been built by the time production ended in 1988.

35. Yakovlev Yak-141 Freestyle

The Yak-41 program was initiated in 1975, about the same time that the Yak-38 was first being deployed. The supersonic Freestyle was optimized for air defense with an attack capability as a secondary role. The first conventional flight was made on 9 March 1987 and the first hover on 29 December 1989. The first official details were not released by the Soviet Union until the 1991 Paris Air Show (redesignated as the Yak-141) by which time the two flying prototypes had accumulated about 210 hours in the air. A dozen FAI-recognized Class H. III records for V/STOL were set in April 1991, consisting of altitudes and times to altitudes with loads. In flight testing, the Freestyle achieved a maximum speed of 1.7 Mach, and maneuverability was repeatedly claimed to be almost as good as that of the MiG-29 Fulcrum (although the small wings of the Freestyle make this extremely doubtful). Flight testing was originally intended to continue until 1995, but development was stopped in August 1991 due to the shrinking Soviet military budget. Yakovlev's funding the development from its own resources for a while, in the hopes of attracting a foreign investor. The second flight prototype was destroyed after a hard landing on the Admiral Gorshkov aircraft carrier on 5 October 1991. The following year, the surviving prototype was demonstrated at the Farnborough Air Show, but the design bureau was still unable to find a market for the design.

Tip Jets

A compound autogyro transmits full power to the rotor for vertical flight, and transfers power to a horizontal propulsion device for forward flight with wings providing lift to allow the aircraft to fly faster than a conventional helicopter. Tip Jet aircraft pump fuel and compressed air to small burner chambers at the rotor tips. This combustion generates thrust which turns the rotor.

36. McDonnell XV-1

McDonnell's tip jet autogyro, the XV-1, was powered by a single 550 hp Continental R-975-19 nine-cylinder radial piston engine. It drove two air compressors to power the 31 ft three-bladed rotor for vertical lift, and powered a 6 ft diameter two-bladed propeller mounted at the rear of the fuselage for forward flight. A small rotor at the end of each tail boom provided yaw control. Overall length was 80 ft, with a 26 ft wingspan. Empty weight was 4,300 lb which
increased to a maximum gross weight of 5,500 lb. First tether test was in 1954, with the first free flight on 11 February of that year. First transition to horizontal flight was on 29 April 1954. The second of the two aircraft was damaged in autorotation testing in December 1954. On 10 October 1955, the XV-1 exceeded contemporary rotor-wing speed records by hitting 200 mph. With conventional helicopters improving their cruise speeds, however, the program was canceled in 1957.

37. Fairey Rotodyne

The British company Fairey had built several compound helicopters in the 1940s. One of these was modified with tip jets as the Jet Gyrodyn in 1953. Based on this data, Fairey designed the 33,000 lb Rotodyne, a 40 passenger transport powered by two 2,800 shp Napier Eland 5 turbine engines. The fuselage was 59 ft long with nearly 3,300 cubic feet of internal volume, ending in rear clamshell loading doors. The 60 ft diameter four-bladed rotor was rotated by tip-jets in vertical flight and autorotated in cruise, providing about half of the aerodynamic lift. During transition, the engine power was transferred by hydraulic clutches to two four-bladed tractor propellers mid-mounted on the 46 ft wide wings. In hover and forward flight, yaw was controlled by differential propeller pitch, while pitch and roll were produced by the cyclic rotor pitch. Aerodynamic surfaces augmented control in forward flight. First flight in helicopter mode was on 6 November 1957. The first transitions were begun in April 1958, with problems making satisfactory tip jet relights at altitude being solved by that October. Tip jet noise was extremely unpleasant, driving a significantly modified production version with lower pressure tip jets. Despite apparent commercial interest, Fairey was taken over by Westland, causing the program to fizzle out in about 1962.

Augmented Power Plant for Hover

This class of aircraft used the powerplant(s) to drive an auxiliary device (either ejector augmentors or lift fans) to provide additional vertical thrust in hover.

Ejector

Ejecting high pressure engine efflux into a channel (called an augmentor) causes additional cooler ambient air to accelerate through the channel and mix with the engine exhaust. As the exit of the augmentor, the combined flow produces more thrust than the input engine efflux; the net increase is the amount of augmentation. In laboratory tests, thrust augmentation of 1.5 to 2 times engine thrust was achieved. In reality, incomplete mixing, duct losses, unanticipated high weight and ram drag, and the huge volume required for the augmented jet ejector systems caused the theory to be difficult to apply to a possible operational concept.

38. Lockheed XV-4A Hummingbird

Lockheed began private research into ejector augmentation systems for VTOL aircraft in 1959. They received a US Army contract in July 1961 to build two of their Hummingbird aircraft as the XV-4A. The Hummingbird had a wingspan of 26 ft, and a length of 32 ft, primarily consisting of a boxy fuselage that housed the ejectors and augmentors. Along each side of the aircraft, a Pratt & Whitney JT12A-7
turbojet engine produced 3,300 lb thrust either for horizontal flight, or diverted into the augmentor ejectors for vertical take-off and landing. The two engines fed interleaved ejectors in case of engine failure. In transition, one engine was diverted from the ejectors to providing forward thrust, until wing-borne lift allowed the second engine to do the same; the augmentors doors were then closed. The augmentors were constructed of stainless steel and titanium, accounting for a significant portion of the 5,000 lb empty weight and the 7,200 lb gross weight. Actual vertical thrust after installation losses was about 7,500 lb for a 1.04 thrust-to-weight. This was only a 14% net augmentation. First conventional flight was on 7 July 1962. First tethered hover on 30 November of that year was followed by first free hover on 24 May 1963. First transition was not completed until 8 November 1963. The first aircraft crashed on 10 June 1964, killing the pilot.

39. Rockwell XFV-12A

Rockwell International's XFV-12A was a supersonic fighter/attack "Thrust Augmenter Wing" concept. The design used a modified 30,000 lb thrust (in afterburner) Pratt & Whitney J401 engine (a larger Navy cousin of the F100 which was canceled before production). For vertical lift, a diverter valve in the engine exhaust system blocked the nozzle and directed the gases through ducts to ejector nozzles in the wings and canards for vertical lift. The thrust of the spanwise ejectors could be modulated by varying the diffuser angle: pitch and roll were controlled by differential variation of the four ejectors from front to aft and left to right; yaw was controlled by differential ejector vectoring. An auxiliary engine inlet for use in vertical flight was located immediately behind the cockpit. The prototype aircraft used parts from the A-4 and F-4; the fuselage was 44 ft long with a 28.5 ft wingspan and a 12 ft canard span. Operational vertical take-off weight was expected to be 19,500 lb, with a maximum speed of over Mach 2 anticipated by Rockwell. Engine rig testing began in 1974, aircraft ground testing in July 1977, and suspended tether trials conducted in 1978. Only one of two contracted aircraft was completed in order to curtail increasing costs. Lab tests were interpreted to show that 55% augmentation could be anticipated, but differences from the lab models to the full scale system caused the actual augmentation to be only 19% for the wing and 6% for the canard. Lift improvement testing and plans to modify the ejector/augmentor system were discontinued in 1981 due to cost overruns and waning Navy V/STOL interest.

Fan
By driving a horizontal oriented ducted propeller or fan buried in the aircraft wing or fuselage, engine power can be redirected to provide increased vertical thrust for hover around the center of gravity.

40. Vanguard Omniplane
In February 1959, two former Piasecki engineers formed the Vanguard Air and Marine Corporation to design and build an executive VTOL aircraft. Their first design, the Model 2C Omniplane used a 25 ft long Ercoupe light plane fuselage and weighed 2,000 lb. The round wings each housed a 6 ft diameter three-bladed propeller that was mechanically driven for vertical flight by a 265 hp Lycoming O-540-A1A six cylinder piston engine. During forward flight, covers above the rotors and louvers below sealed the wing for aerodynamic lift. Forward thrust was produced by a 5 ft diameter shrouded propeller in the tail. Elevator and rudder surfaces immediately behind the rear fan controlled pitch and yaw, while differential propeller blade pitch af-
fected roll in hover. Ground tests, starting in August 1959 and including tethered hover trials, were followed by NASA full-scale wind tunnel testing. Modifications to the Omniplane in 1961, including an improved control system, upgrading to a 860 hp Lycoming YT53-L-1 turboshaft engine, and 5 ft nose extension to house a third lifting propeller, led to the redesignation 2D. The nose propeller improved control in pitch as well as in yaw, through the use of movable exit vanes. The 2D completed tethered hover tests, but was damaged by a mechanical failure and discontinued in early 1962.

41. GE-Ryan XV-5A Vertifan

After two years of research, in November 1961, General Electric won a US Army contract to develop its fan-in-wing concept, the XV-5A. Design, construction and flight testing of the aircraft was sub-contracted to Ryan, but GE retained responsibility for the propulsion system and its integration into the aircraft. The XV-5 was 44 ft long with a 30 ft wingspan. In the inboard portion of each wing a 5 ft diameter fan provided vertical lift. A smaller fan in the nose in front of the two person cockpit give pitch control and additional lift. The fans, providing a total vertical thrust of 16,000 lb, were driven by the exhaust gases of two 2,650 lb thrust GE J85-GE-5 turbojets. With a 7,000 lb empty weight, and a 12,200 lb gross weight, the Vertifan had 31% excess power. The wing fans rotated in opposite directions and were covered by hinged doors, while the nose fan was covered by louvers. The wing fans, which differentially affected roll, exhausted into louvered vanes that could vector the thrust fore, aft or laterally, also controlling yaw. A thrust spoiler allowed the engines to throttle to full power before the fans were started. Two aircraft were built; the first one flew from 25 May 1964 until it crashed the following April, killing the pilot during a transition attempt. First hover was in June 1964, and first transition in November 1964. The second aircraft flew until it crashed in October 1966 (also killing the pilot), but was rebuilt as the XV-5B. This had a wider landing gear, an improved cockpit, and removed the thrust spoiler. It began flying on 24 June 1968. The drawbacks of the Vertifan were the large volume and weight occupied by the lift system, slow control response, and the narrow transition corridor.

42. Lockheed Martin X-35

As part of the Joint Strike Fighter (JSF) program, the Lockheed Martin X-35 concept demonstrator (artist’s drawing above) will use a derivative of the Pratt & Whitney F119 engine. In short take-off and vertical landing (STOVL) mode, the engine drives a shaft which turns an Allison lift fan, ahead of the center of gravity. Doors above and below the vertically mounted lift fan open before it spins up. The rear lift force and yaw control is provided by a swiveling exhaust nozzle from the engine, similar to that of the Yak-141 (#35). Roll control is provided by two roll nozzles using ducted engine fan bypass air. First flight is planned for 2000. The winner of the JSF source selection in 2001 will then develop its operational version of the concept as a supersonic multirole aircraft to replace the Harrier. Lockheed Martin tested a 86% scale F100-powered model in 1995-1996 for nearly 200 hours including testing in NASA’s full sized wind tunnel.

Rotor

For design missions where the aircraft needs to spend a large amount of time in hover, the rotor is the most efficient lifting device. However, it is very difficult for the rotor to propel the aircraft forward and provide lift at a high velocity. In order to increase maximum velocity, a variety of methods have been used to add propellers and wings to rotor aircraft, forming compound helicopters.
43. Kamov Ka-22 Vintokryl ‘Hoop’

The Ka-22 Vintokryl (‘Screw Wing’) was a large twin-turboshaft powered convertiplane that debuted at the Soviet National Aviation Day display on 9 July 1961 in Tushino. At each end of the high, straight wing, was a 6,500 shp Soloviev D-25VK engine which powered a four-bladed rotor for vertical flight and a four-bladed propeller for cruise. Each engine was progressively clutched between the two systems to transition between the two modes of flight. The engine was a nine-stage single spool turboshaft modified from the 5,500 shp D-25V engine used on the Mil Mi-6, Mi-10, and V-12 helicopters. The final turbine stage was a free-wheel that drove the gearbox. The fuselage housed a loading ramp that could be used for freight or vehicles, and could carry 36,400 lb of cargo or 80 seats (although this was never done). The tricycle landing gear was fixed and the entire nose area was glazed for good visibility, especially in landing. The high flight deck accommodated two pilots, a radio operator and engineer. Flight testing began on 20 April 1960. On 7 October 1961, the Vintokryl set a Class E. II speed record of 221.4 mph over a 15/25 km course. On 24 November 1961, it lifted a record payload of 36,343 lb to a height of 6,562 ft (2 km), as well as several other payload to altitude records. The Ka-22 was abandoned after a crash in 1964.

44. Piasecki 16H-1 Pathfinder

The 37 ft long privately developed Piasecki 16H-1 weighed 11,000 lb and had a wingspan of 20 ft. The five-seat Pathfinder was originally powered by a 550 hp Pratt & Whitney PT6B-2 turboshaft engine. The engine powered a 41 ft fully articulated three-bladed rotor and a 5.5 ft three-bladed ducted propeller in the tail (called a “ring-tail”) to provide forward thrust and directional and anti-torque control with four vertical vanes in the duct. Gross weight was 2,611 lb and fuselage length was 25 ft. The 16H-1 made its first flight on 21 February 1962. Overall, the Pathfinder had the handling qualities of a conventional helicopter, but used its wings and pusher propeller to off-load the rotor and increase its maximum forward velocity to 148 kt. 185 flight hours were accumulated before May 1964, when Piasecki was contracted to test a high speed modification, the 16H-1A Pathfinder II. It was equipped with a 1,250 shp T58 turboshaft engine, a new drive system and propeller to handle the increased power. The rotor size was increased to 44 ft diameter, and the fuselage was stretched to accommodate eight seats. Flight testing resumed on 15 November 1965 and it accrued over 40 hours in the air by May 1966, reaching speeds of 195 kt. Later, it was redesignated the 16H-1C when the engine was upgraded to a 1,500 shp T58-GE-5.

45. Lockheed AH-56 Cheyenne

Lockheed research into compound rigid rotor helicopters began in the early 1960s using the XH-51. In 1966, Lockheed's design for an operational attack helicopter, the AH-56 Cheyenne, won the contract to build the US Army's Advanced Aerial Fire Support System (AAFSS). The Cheyenne had a 3,435 shp General Electric T64-GE-16 turboshaft engine that powered a rigid 50 ft four-bladed rotor, as well as a 10 ft three-bladed pusher propeller and a four-
bladed anti-torque rotor on the tail. In horizontal flight, almost the entire engine output is used to drive the propeller. The AH-56 weighed 12,000 lb empty, had a 55 ft long fuselage and a 27 ft wingspan. Maximum vertical take-off weight was 22,000 lb, but a short take-off could be made at 28,000 lb. First flight was on 21 September 1967. The maximum design speed of over 250 mph could not be reached, however, due to a dangerous rotor instability above 200 mph. The third of ten prototypes crashed on 12 March 1969 when the rotor impacted the front and rear fuselage, killing the pilot. The AH-56 was highly agile and a very capable weapon system, but development was halted in 1972, due to defense cutbacks. A production order of 375 AH-56s had been approved in 1968, but canceled the next year, also as a result of budget cuts.

Aircraft That Didn't Make The Wheel:

A strict set of criteria was used to select the aircraft for the wheel of V/STOL Aircraft and Propulsion Concepts. Only aircraft which were actually tested, with the intention to demonstrate or develop an operational aircraft concept capable of vertical or short take-off and landing and conventional forward flight were selected (although the JSF X-32 and X-35 concept demonstrators will not fly until 2000, they are included for illustrative purposes). Aircraft that did not meet these criteria included:

- Platforms, ground effect machines, conventional helicopters and autogyros, and purely STOL aircraft;
- Numerous design studies, such as the EWR-Republic V/STOL, Convair 200, Sikorsky X-Wing, and others that were never built; and
- Research helicopters, where a jet engine was used solely to increase maximum speed, such as the Lockheed XH-51A, the Fairey Jet Gyrodyne, the Sikorsky S-72 Rotor Systems Research Aircraft, and the Sikorsky XH-59 Advancing Blade Concept (ABC).

Vision for the Future:

Over the past half-century many different types of V/STOL aircraft have been built and tested, while many more never left the drawing board. Today, the future looks bright for V/STOL. In the next half-century, we will see the V-22 Osprey achieve operational service, as well as a possible commercial tilt rotor. The Harrier will end its respectable career, but the supersonic STOL Joint Strike Fighter will enter the inventories of the US Marine Corps and allied nations. The second half-century of V/STOL promises to be even more exciting than the first.

About the Author:

Mike Hirschberg is an aerospace engineer at ANSER, Inc. He currently supports the Propulsion Management Team for the Joint Strike Fighter Program. Previous positions have included supporting the Assistant Secretary of the Air Force for Acquisition on the F-22 advanced tactical fighter and F119 engine programs, and working as a project engineer on various solid rocket motor development programs. He has authored several papers on engine development and V/STOL aircraft, including the upcoming AIAA Case Study on Soviet V/STOL Aircraft.

Further Reading:


Credits:

- V/STOL wheel graphic by Mike Hirschberg and Jack Butler, ANSER. For an electronic copy of the V/STOL wheel, visit the AHS Web Site at http://www.vtol.org.
- Thanks to Sam Wilson, NASA, and Hal Andrews, DGI, for their invaluable assistance with the graphic and the article.

FORUM 53 attendees can participate in the Joint Strike Fighter '97 Symposium on Tuesday, April 29, 1997 and in a special V/STOL Session on Thursday, May 1 from 8:00-11:00 a.m., moderated by Sam Wilson, NASA Liaison to the JSF Program Office.
Aircraft Survivability Symposium
"Vulnerability Reduction Technology"

October 21-23, 1997
Naval Postgraduate School
Monterey, California

Sponsored by The American Defense Preparedness Association (ADPA), Combat Survivability Div., the FAA, AIAA, the Joint Technical Coordinating Group on Aircraft Survivability, and the AHS.

Why This Symposium?
Combat survivability considerations are essential inputs to the military aircraft design process. Pending procurements of new fixed and rotary wing aircraft call for a review of vulnerability reduction technologies and the promise for improvement. As one of survivability's twin elements, vulnerability reduction measures seek to reduce the probability of loss of an aircraft if damaged by enemy action. Certain of these measures are applicable to commercial aviation as well. And in recent years, there has been increasing intent by the commercial aviation sector to employ these vulnerability reduction technologies and methods to minimize damage resulting from terrorist acts and to enhance overall safety during regular peacetime flight operations. The symposium will examine current and emerging technology development and systems applications that can enable aircraft to withstand threat damage (vulnerability reduction) and how they can be balanced with threat avoidance techniques (susceptibility reduction).

What Will Be Covered?
This symposium is designed to increase awareness and foster technology interchange across the military, government and commercial aviation sectors. Invited speakers, selected papers, and panel discussions will examine operational requirements, system designs, latest threat intelligence, emerging vulnerability reduction technologies, assessment methodologies, as well as affordability and integration issues.

For more information contact the ADPA at (703) 522-1820, Fax (703) 522-1885 or by e-mail at mbilowich@adpa.org. Refer to ADPA event #894.
Reading the Journal for Fun and Profit: 
The April 1997 Issue

The April issue of the AHS Journal contains 8 articles and a Technical Note on a total of eight different disciplines. There's something here for almost everyone. Four of the nine papers are from the '95 or '96 Forums of the AHS, two are from specialists' meetings and three are new publications. Hopefully, the summaries below will whet your appetite and you will want to read the Journal and try to profit from the work of others.

“Results from the NASA Automated Nap-of-the-Earth Program” by R. Zelenka and co-authors at NASA Ames summarizes several years of research involving analysis, hardware and software development, simulation and flight test. The four major elements of the program are: 1) development and evaluation of passive sensors (cameras) to extract range and position of obstacles, 2) demonstration of active sensors (radar) to position objects and terrain, 3) use of pilot displays driven by a terrain database and sensors for assisted low altitude flight, and 4) NOE flight on the simulator with similar displays plus an active obstacle avoidance system. Efforts continue on merging the various data sources and refining the pilot interface for this most demanding operation. This paper was chosen as the “Best Forum Paper” in 1996.

“Analytical Crash Simulation of Three Composite Fuselage Concepts and Experimental Correlation” by Karen Jackson of the Army's Langley Center reports on a fairly unique set of analyses and tests. Two, all-composite Lear Fan airframe sections were made available for modification and destructive (drop) tests. The DYCAST crash analysis code was applied to each configuration and correlated with the results. Lessons learned were numerous, and good correlation was shown possible once the important input parameters were understood. The best fuselage concept provided a 50% reduction in the acceleration of a simulated occupant.

“Results of an Aeroelastic Tailoring Study for a Composite Tiltrotor Wing” by D. Popela, D. Baker and co-authors at Bell shows the results of an analytical study applied to a hypothetical commercial V-22 wing. The goal is to retain the prop/wing stability margins while reducing its thickness from 23 to 18% in order to improve the performance. The wing is tailored by optimizing the orientation and thickness of the wing skin laminates and the number and stiffness of the stringers. Beamwise bending, chordwise bending and wing strength are all considered. A 24 knot speed improvement over the untailored wing was calculated at a modest weight penalty.

“Mil Design Bureau Heavy Lift Helicopters” by Marat Tishchenko is a fascinating technical narrative of the development of the V-12 and Mi-26 helicopters. The side-by-side V-12 at about 200,000 pounds gross weight flew in 1967. The production single rotor Mi-26 flew in 1978, at about 106,000 pounds with a 105-foot rotor. Optimization studies of major components are discussed and configuration pros and cons at such large sizes are cited often. This is a rare glimpse at the workings within the Mil Design Bureau during the decades when it was largely a mystery to the outside world.

“Robust Multivariable Control of Rotorcraft in Forward Flight” by Rozak and Ray, presents the analysis of a variety of control systems applied to the UH-60 Blackhawk to meet the ADS-33C Spec. The goal is “robustness” in that upsetting turbulence or noise or out-of-trim conditions do not negate the stability provided. A rate-command 3-axis system with an ideal model structure was shown to give the best overall performance. The reasons for this are well explained, but the actual methodology of the analysis is covered by the references.

“Detection of Helicopter Rotor System Simulated Faults Using Neural Networks” by Ganguli, Chopra and Haas is an analytical study of a sophisticated way to detect rotor system faults in flight. In the sample cases, applied to an H-60 rotor, the faults simulated were moisture absorption, lag damper degradation and pitch link damage. Realistic noise levels are added to sensor signals. A feedforward neural network with back propagation learning was trained using both ideal and noisy signals. The system could detect damage from noisy measures of rotor forces and moments. A system trained on noisy data gave a more accurate picture of the extent of the damage.

“An Efficient and Robust Method for Computing Quadrupole Noise” by Brentner and Holland presents a new far-field approximation to the Fioves Williams - Hawkings quadrupole source noise applicable near an in-plane observer. Quadrupole sources are an important part of rotor
noise at high Mach numbers, but they have not been routinely included because of computing complexity. The method presented here leads to quadrupole integrals of the same form as thickness and loading noise and requires comparable computer resources. Correlation with experimental data for a hovering rotor at Mach 0.9 shows good agreement.

“Effects of Surface Blowing/Suction on the Aerodynamics of Helicopter Rotor Blade-Vortex Interaction (BVI) - A Numerical Simulation” by Hassan et al. of MDHS looks at the possibility of a novel means of active noise suppression. Blowing or suction normal to the surface of an airfoil can effectively change the thickness or camber of the airfoil. If this is done selectively when the blade comes in proximity to a blade wake, fluctuating pressures and the resultant BVI noise can be substantially reduced. This analytical study is a first step in exploring the feasibility of such a system. A sample case of the MD-900 rotor in low speed descent is used for illustration.

“Prediction of the Flow Field of a Rotor in Ground Effect” by Ning Kang and Mao Sun of Beijing University is a Technical Note. They report on the solution of the three-dimensional, steady, incompressible laminar Navier-Stokes equations in Cartesian coordinates for the complex problem of a rotor in low speed flight near the ground. Predictions of wake distortion and the formation of a ground vortex show good agreement with experimental results.

Dr. David S. Jenney, prior Director of LH Engineering for Sikorsky, is also the recipient of an AHS Honorary Fellowship and the winner of the 1996 Alexander A. Nikolsky Honorary Lectureship.

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Application of Composites in Commercial Helicopters

by Joyanto K. Sen
McDonnell Douglas Helicopter Systems
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Introduction

The helicopter can climb vertically, fly forward, sideways, and rearward, all without changing its orientation or attitude. In addition, it can hover. The rotor components which allow these maneuvers to be performed are complex in design and are subjected to high combined loads and large deflections. Powered by engines rotating at around 45,000 rpm, the main rotor speed is reduced to around 300 rpm by a 3-stage main transmission gearbox. Consequently, the weights of the rotor and the drive systems are high, and, as a result, the empty weight fraction of the helicopter is higher than that of fixed-wing aircraft. Since the helicopter performance and cost is sensitive to weight, alternate materials and the development of innovative designs are constantly sought.

Early helicopters used wood extensively in primary structures. In order to reduce manufacturing cost, designs of wooden structures were simple (e.g., blades had rectangular plan form and no twist) and often heavy (e.g., frames of heavy wood were not adequately laminated with light wood), both at the expense of helicopter performance. Metallic materials alleviated some of these problems. The successful transition to metals was achieved by balancing their higher strengths and stiffnesses against their higher densities by advances in design, manufacturing methods and construction techniques.

Composites are an attractive alternative to metals because their strengths and stiffnesses are comparable to those of metals while their densities are low. Because of improved damage tolerance and reduced susceptibility to corrosion, under environmental influences and service operations composite structures generally tend to degrade progressively in strength and stiffness instead of developing potentially dangerous (micro) cracks as in metallic materials. Composites, therefore, have excellent fatigue characteristics and exhibit benign failure modes. Long before complete separation, composite structures show evidence of overload conditions by delaminating. In addition, composite materials can be tailored to the desired strength and contoured accurately to the complex shape of a structure.

In 1952, twelve Hiller Hornet ramjet-driven helicopters with airframes of fiberglass sandwich construction were flown and evaluated by the US Army. Ref. 1. Between 1948–1956, several experimental fiberglass rotor blades were ground- and flight-tested. Even then composites application remained limited to secondary structures until 1968. Composites used in helicopters are organic matrices with glass, carbon and aramid fibers. The use of thermoset epoxies is overwhelmingly greater than thermoplastics, whose applications have been limited to specific airframe components. The major advances have been in the dynamic components of the rotor system of the helicopter where composites have provided the greatest benefit: a lighter structure with superior fatigue characteristics and lower life-cycle cost. Composite application in airframes has been slow, mainly because cost and weight benefits are limited, and existing design approaches had been unchallenged. Composite structures from all manufacturers have been certified, however, the advantages of the wide use of composites were proven in two technology demonstrators: the all-composite Boeing 360 helicopter and the all-composite fuselage of Eurocopter Deutschland’s BK.117.

The Helicopter

The helicopter is a complex dynamic system because of “definite instabilities in some regimes of flight.” (Ref. 2). The conventional helicopter is controlled in flight by the main and tail rotor systems. Vertical, longitudinal, lateral and directional control are achieved by either directing the main rotor thrust vector, or generating moments about the rotor hub, or a combination of both. In designing helicopter rotor systems with high maneuverability and for a smooth ride while accommodating changes in moments and forces, and large deflections, design configuration parameters are often in contradiction with the need to keep the empty weight and cost low.

The unique features of the helicopter come at the expense of payload efficiency and direct operating cost (DOC), both of which are higher for helicopters than for light turbo-prop aircraft for the same range and maximum take-off weight (MTOW). The payload efficiencies, in terms of the work done (payload range) per pound of empty weight, are compared in Fig. 1 for helicopters and aircraft with MTOW between 3,000 lb. and 20,000 lb. (Ref. 3 and 4). Empty weight is defined as the MTOW less the payload, fuel, oil, and other expendable. In this weight range, which includes over 90% of the world’s helicopters, aircraft are generally three times as efficient as heli...
A typical articulated main rotor, developed for metallic materials, is shown in Fig. 3. The major components of the main rotor system are the mast, the central hub and the blades. In flight, the rotating blades are subjected to high loads and large deflections as they continuously change from an advancing to a retreating position and back. The blade loads consist of a constant centrifugal force, and fatigue loads of in-plane and out-of-plane bending moments, a twisting moment and shear. The blade loads are reacted by the hub and the deflections accommodated by hinges in three planes. Dampers are added to reduce vibrations and eliminate dynamic instabilities.

The use of hinges, bearings and dampers in the rotor system alleviates some of the design problems but adds complexity and weight, and increases parts count and cost. The metal rotor design is a safe-life design, where early detection of failure is often difficult. Composite rotor systems, in contrast, are fail-safe in design with "on-condition" retirement lives and benign failure modes. Composites rotors are simpler in design, have reduced parts count, and have fatigue strengths and damping characteristics tailored to the desired mechanical response.

The main rotor is mounted on the mast and driven by the main transmission. The main transmission and the engines are supported on the upper deck of the fuselage. The tailboom, attached to the rear of the fuselage, provides the desired moment arm for the anti-torque system and the stabilizing surfaces. A long moment arm improves control sensitivity but also increases airframe weight and drag. The airframe is designed for low parasitic drag, low moment coefficients, and a center of gravity located as far below the rotor center as possible to improve control characteristics. The high vibrations felt in the cabin are reduced through isolators or by other means. Composites in airframes reduce weight and cost by minimizing joints and other labor-intensive operations, and reduce cabin vibrations and noise through choice of material and design.

Any reduction in the empty weight fraction increases payload and operating range while reducing the fuel consumed. A ten percent reduction in empty weight can translate into a 30 percent increase in payload or a 40 percent increase in range. In addition, the DOC of helicopters can be reduced with increased retirement lives and on-condition maintenance of its dynamic components. Composites provide the tools with which to meet these challenges.

**Trends in Composite Applications**

Composites in helicopters were initially applied to interior trim and secondary structures of the airframe by all manufacturers, and consisted of less than 5 percent of the helicopter's empty weight. Large-scale application, however, in rotor components began in Europe in the late 1960s and in the USA in the 1970s. Fig. 4 (Ref. 6-11). The first composite primary component was the main rotor blade of Eurocopter Deutschland's Bo 105 helicopter which flew in 1968, Ref. 12. With glass composite main rotor blades, and rear doors, front and aft fuselage shells and engine fairings made of glass sandwich construction, the Bo 105 had 13 percent of its empty weight in composites. The Starflex hub, the first all-composite rotor system, was certified in 1974 for Eurocopter France's AS 350 Ecureuil, which had a composite content of 18 percent of its empty weight.

In the USA, Boeing's all-composite main rotor blade flew in 1974 on the CH-47 Chinook helicopter, which had a total of 8 percent in compos-
Composites in Helicopter Design

Composites have very low densities while their tensile and fatigue strengths, and stiffnesses are comparable to, or higher than, those of metals. The effectiveness of composites over metals are best expressed in terms of their specific strengths and stiffnesses, which define these properties in terms of weight per unit volume. The specific tensile and specific fatigue strengths of typical composites and metals are compared in Fig. 5 and 6 in terms of their specific moduli (Ref. 13-18). The choice for the most effective material depend on the application. For general purpose applications, glass composites are chosen when higher strength is desired, Fig. 5. Even though composites of the aramid fiber, Kevlar-49, and high-strength (HS) carbon exhibit considerably higher specific strengths and moduli, glass is preferred for its lower cost. Kevlar composites are rarely used without reinforcement in primary structures because its compression strength is only 20 percent of its tensile strength compared to 50 percent for glass and 100 percent for carbon.

Since helicopter rotors are subjected to high, complex fatigue loads and very large deformations, they are designed with high fatigue strengths and low stiffnesses. Glass composites are the primary material for rotor components. They offer a higher specific fatigue strength in comparison to metals for the lowest specific stiffness (moduli) of all composites, Fig. 6. The fatigue strengths, shown in the figure, are at 10^7 cycles for a stress ratio of R=0.1. In addition, glass composites exhibit a benign failure mode which can be detected and repaired, and the component returned to service. Carbon is only applied selectively to reinforce strength or stiffness of rotor components.

For fuselage structures, which are shells designed to react shear and torsional loads, the minimum gage concept of conventional metal designs are inefficient with composites. The higher strength of composites make for over-designed structures with inadequate tolerance to damage. Post-buckled tension-field composite shear panels have the efficiency necessary to save weight over similar aluminum designs. In diagonal tension static tests, Fig. 7, the shear flow...
per unit panel weight of monolithic HS-carbon and Kevlar are, respectively, 2.5 and 4 times greater than that of aluminum, Ref. 19. The difference in the fatigue strengths of ±45° HS-carbon and Kevlar laminates and aluminum specimens are marginal. Since fuselage shear panels of commercial helicopters are designed for shear loads of less than 300 lb./in., which is less than 10 percent of the fatigue shear allowable, design trade-off studies are based on static shear flow strength. HS-carbon and Kevlar shear panels are 30 to 45 percent more weight efficient than aluminum panels, Fig. 8, Ref. 20. Carbon sandwich panels with Nomex core are more weight efficient than aluminum panels for shear flow in excess of 300 lb./in., and monolithic HS-carbon and Kevlar panels for shear flow in excess of 700 lb./in.

Composite structures consist of multiple plies, each ply with its own unique orientation to tailor to the specific requirements of the structure. As the ply orientation changes, the mechanical properties change. As shown in Fig. 9, where the moduli are normalized by the respective modulus for 0° fiber angle, the extension modulus, $E_{xx}$, of the laminate decreases rapidly with increasing fiber angle while the variation in the shear modulus, $G_{xy}$, is less pronounced. Poisson's ratio, $v_{xy}$, and the coefficient of mutual influence of the second kind, $b_{xy}$, which generate high interlaminar stresses when adjacent plies are mismatched, exhibit large variations with increasing ply angle. In tailoring composite structures, the plies and their orientations are selected to maximize strength and reduce the effect of mismatched plies.

The specific tensile and fatigue strengths (for $R=0.1$ at 10$^7$ cycles) of
composites, the blades are of glass composites reinforced by carbon composites in the spar and the inboard end. In heavy helicopters, the proportion of carbon composites in blades is greater than glass. The aerodynamic contour is formed either by filament winding rovings or laying up tape. The design of the trailing edge, which can dictate the final weight of the blade, is either attached separately or is integral with the remainder of the blade.

The main rotor blade of the Bö 105 helicopter is made of glass-composites. The blade skins and spar are made of E-glass-epoxy. The skins are of woven cloth at ±45° while the C-shaped spar is made of unidirectional rovings. The after-body has a hard PVC foam core, Ref. 26. The flexible shank at the inboard end of the blade acts as hinges for flap and lead-lag motions, Fig. 14.

The composite blade of the Boeing 234 helicopter was designed to match the existing metal blade with the exact same dynamic characteristics, stiffnesses and load distribution as the metal blade, Ref. 8. The glass composite D-shaped spar of the blade is made of unidirectional strips and ±45° spar skins, Ref. 27. The blade skins are made of a hybrid of high-modulus carbon and glass composite, wrapped at ±45° around a Nomex honeycomb core. The trailing edge consists of a Nomex honeycomb core supported between ±45° glass skins.

Since 1970 Boeing has produced over 7,400 blades for commercial and military helicopters. These composite blades, which require 80 percent fewer manufacturing hours than metal blades, have on-condition service life and have never experienced catastrophic failure. Blades, once repaired, are returned to service. Some composite blades on Boeing 234 helicopters, operated by Columbia Helicopters, have over 20,000 hours.

The composite main rotor blade of the MD 900 Explorer is made of S2-glass. It is aerodynamically tailored with a twist and a tapered plan form to maximize performance. The twist is pronounced at the inboard end but drops to half the initial value within 30 percent of the blade radius. The spar, made of unidirectional and ±45° plies, transitions from two pairs of lugs at the inboard end to a D-shaped cross section. A core of Nomex honeycomb is enclosed by skins made of prepreg rovings wound at ±45° to react the torsional load and unidirectional tape for additional bending stiffness. A protective ply of E-glass cloth covers the skin. The blade has a parabolic tip over the last four percent of its span. In comparison to a metal blade, the composite blade of the MD 900 is 16.5 percent lighter.

As a compromise between requirements and design configuration parameters, existing main rotor blades are "optimized" for a particular segment of the flight envelope, Ref. 28. Otherwise, the blade would have a continuously varying geometry with multiple airfoils, non-linear twist and taper, and a highly contoured tip. In addition, the blade should be able to adapt its geometry to the most desirable configuration while in flight to meet changing requirements. The fabrication of such a blade using metallic materials is commercially impractical. Composite manufacturing methods have the versatility required to fabricate such blades even though they have not evolved to these optimized designs. Some advantageous use of composites have already been made by including swept tips, and adding limited non-uniform taper and twist. To apply composites effectively, however, advanced tools are necessary to address aerodynamic and structural factors simultaneously with ease of manufacturing during design.

Westland's "BERP" (British Experimental Rotor Programme) blade, which was flown on a modified Lynx helicopter in 1986, demonstrated the effectiveness of variable geometry blades. The program was initiated to improve performance in forward flight by reducing transonic effects and increasing rotor thrust, Ref. 29-31. The blade includes three high-lift airfoils which are ordered to make the blade progressively thinner towards the tip. The outboard 15 percent of the blade span was first swept back to reduce transonic effects, which then required increasing the plan form area to offset adverse control problems, thus resulting in the characteristic leading edge hump of the BERP blade, Fig. 15. The extreme leading edge was swept sharply back and twist was added to the initial 85 percent of the blade span. The Lynx with the BERP blade set a new world speed record of 216.8 kts (249.1 mph or 400.87 kph). The difference from earlier high-speed flights by helicopters was the low level of main rotor induced vibration throughout the speed range. Earlier flights of the Dauphin and the upgraded Mil A-10 Hind with conven-
The BERP blade is made of unidirectional E-glass and carbon tape, and glass-carbon hybrid cloth. An automatic tape laying machine where multi-spool carriages laid prepreg strips of tape in the mold over the full length of the blade was used to fabricate the blade. Contour-following brushes smoothed out wrinkles, making it possible to lay tape onto highly contoured molds. The blades were consolidated and cured in self-contained aluminum molds with external pressure and heat in hydraulic presses. A hard foam, machined to tolerances of 0.005 inch, was used as mandrels in the molds.

**Fig. 15. Geometric and aerodynamic features of the Westland BERP blade (Ref. 30 and 31).**

<table>
<thead>
<tr>
<th>Class</th>
<th>Metal Blade</th>
<th>Composite Blade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>SA 319B</td>
<td>SA 341G</td>
</tr>
<tr>
<td>&lt;5,000 lb.</td>
<td></td>
<td>Bo 105</td>
</tr>
<tr>
<td>Medium</td>
<td>Bell 205A-1</td>
<td>SA 305N</td>
</tr>
<tr>
<td>5,000-10,000 lb.</td>
<td></td>
<td>BK.117A</td>
</tr>
<tr>
<td>Large</td>
<td>Bell 212</td>
<td>S-76B</td>
</tr>
<tr>
<td>10,000-15,000 lb.</td>
<td></td>
<td>SA 330J</td>
</tr>
<tr>
<td>Heavy</td>
<td>S-01N</td>
<td>SA 332L</td>
</tr>
</tbody>
</table>

**Fig. 16. Comparison of life-cycle costs of main rotor blades.**

Torsional blades were racked by tremendous vibrations and very high specific fuel consumption in the region of 200 knots.

The BERP blade is made of unidirectional E-glass and carbon tape, and glass-carbon hybrid cloth. An automatic tape laying machine where multi-spool carriages laid prepreg strips of tape in the mold over the full length of the blade was used to fabricate the blade. Contour-following brushes smoothed out wrinkles, making it possible to lay tape onto highly contoured molds. The blades were consolidated and cured in self-contained aluminum molds with external pressure and heat in hydraulic presses. A hard foam, machined to tolerances of 0.005 inch, was used as mandrels in the molds.

**Fig. 17. Typical metal skin-stringer construction of a helicopter fuselage.**

**The Composite Airframe**

The airframe of the helicopter can be divided into the fuselage, the tailboom and the stabilizing surfaces of the horizontal and vertical stabilizers. The lightweight metal design of the fuselage and tailboom of current helicopters is typically a skin-stringer construction. A scaffold, Fig. 17, is first constructed of keel beams, bulkheads, frames and longerons to react the vertical and lateral bending moments. The skin and stringers, which terms of lower acquisition and life-cycle costs (Ref. 3). Four classes of helicopters are shown in Fig. 16. The cost in 1992 dollars is along the ordinate, and the service life is given for specific helicopters to be on-condition (O/C) or in hours. Composite blades for three helicopter models in each of the small (up to 5,000 lb.) and medium (5,000 to 10,000 lb.) weight categories are shown. The acquisition costs of these composite blades are either comparable (with one exception) or lower than metal blades. For the large (10,000 to 15,000 lb.) and heavy (greater than 15,000 lb.) weight categories, acquisition costs are between 85 and 197 percent of the respective metal blade. The higher acquisition cost is compensated by the lower life-cycle cost because the service life of the all-composite blade is on-condition. The exception is the 11,750-hour life of the S-76B blade, which is a hybrid of metal and composites.
react shear and torsion loads, are then riveted to the scaffold. The floor, doors, canopies, fairings and cowlings, which are secondary structures, are then added and provide additional stiffness. Secondary structures exposed to the outside are aerodynamically tailored to reduce parasitic drag.

In the 1950s, interior trim and secondary structures were made of glass-epoxy composites. The emphasis shifted in the early 1960s to retrofitting stiffness-critical structures, such as doors and panels. The material of choice was again glass composites. When aramid fibers became available in the 1970s, direct substitution of glass composites with Kevlar composites in secondary structures resulted in 15 to 25 percent weight savings. The helicopter industry at first used carbon composites selectively in highly loaded components because of the high material cost (seven times as expensive as glass composites and three times as Kevlar composites) and because glass and Kevlar composites provided the desired weight savings. In comparison to aluminum, a component of glass composite would typically be 30 percent lighter, of Kevlar composite 45 percent, and of carbon composite 40 percent, Ref. 32. An all-composite airframe for a commercial helicopter is not yet in service because composites have only been applied where weight or cost savings can be maximized. Where composites are used in airframes, the basic skin-stringer approach is retained but stiffened composite panels and co-cured processes have reduced parts count and the number of operations. The technology demonstrators, the Boeing 360 and Eurocopter Deutschland's composite BK.117, used modular sandwich panels to replace skin-stringer construction. The designs of composites in airframes are discussed below.

The airframe of the SA 365N Dauphin is built around metal bulkheads, frames, longerons and stringers, Fig. 18, (Ref. 6 and 23). Sandwich construction, with skins of a light metal alloy, carbon or Kevlar and a Nomex honeycomb core, is used in stiffness-critical structures, such as the aft fuselage, tailboom and webs of the keel beam. The lower fuselage has metal sandwich skins on the bottom, carbon-Nomex skins on the sides in the forward section and Kevlar-Nomex skins in the mid-aft section. The doors and canopies are also of sandwich construction with glass or Kevlar skins. The skins of the floor are of carbon-stiffened Kevlar. The cowlings and fairings have Kevlar or glass skins reinforced with foam or Nomex honeycomb. The horizontal stabilizer and the fenestron are made entirely of composite skins (Ref. 6 and 7). The horizontal stabilizer is a simple design consisting of a single webbed block of monolithic carbon cloth which passes through the tailboom and supports two side fins made of carbon skins wrapped over a Nomex honeycomb core. The fenestron, shown in Fig. 19, has the duct made of carbon-stiffened Kevlar with Nomex honeycomb while the tail cone, leading edge box, ribs and the rotor support tube are of monolithic carbon. Sandwich construction, with Kevlar or carbon-Kevlar skins and Nomex honeycomb or foam core, is used for the fin cap, rear and tail fairing skins, and panels and fins. The total composite content in the Dauphin is 19 percent of empty weight.

The estimated weight and cost savings from the use of composites in the Dauphin are given in Table 1. There is no correlation between weight saved and cost saved. Each is affected differently by the size, the complexity and details of the geometry, and the loads to be reacted. The complex design of the fenestron though well adapted to composites requires considerable touch labor. As a result, the cost of the composite fenestron, even though 18 percent lighter, is an additional 10 percent over its metal coun-
Table 1 Weight and Cost Savings on the Dauphin Airframe

<table>
<thead>
<tr>
<th>Component</th>
<th>Component Material</th>
<th>Weight Saved, %</th>
<th>Cost Saved, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailboom</td>
<td>Light Alloy + Nomex</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Horizontal Stabilizer</td>
<td>Carbon</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Fenestron</td>
<td>Carbon-Kevlar + Nomex</td>
<td>18</td>
<td>-10</td>
</tr>
<tr>
<td>Floor</td>
<td>Carbon-Kevlar + Nomex</td>
<td>20</td>
<td>-70</td>
</tr>
<tr>
<td>Doors</td>
<td>Kevlar</td>
<td>31</td>
<td>60</td>
</tr>
<tr>
<td>Canopies</td>
<td>Kevlar-Carbon + Nomex</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>Cowlings</td>
<td>Kevlar</td>
<td>55</td>
<td>85</td>
</tr>
</tbody>
</table>

In contrast, the floor, a simple, one-piece construction similar to a metal floor, increases cost by 70 percent but reduces weight by 20 percent. The material and construction of choice is, therefore, often a trade-off in the benefits being maximized.

The airframe of the MD 900 Explorer consists of metal bulkheads located along load paths from the transmission deck. The rest of the airframe is almost exclusively of carbon composites, Fig. 20. The longerons and stringers in the lower fuselage are structural elements of monolithic carbon which, together with frames, support sandwich skins of carbon and Nomex honeycomb. The keel beams, the floor and the NOTAR tailboom are also carbon-NOMAR structures. The doors have monolithic carbon skins bonded to metal frames. Cowlings and fairings of monolithic carbon are aerodynamically contoured to reduce parasitic drag and improve performance. The horizontal stabilizer is a two-piece bonded assembly with a spar of monolithic carbon and an after-body constructed of carbon and Nomex honeycomb. The vertical stabilizer, a webbed-box constructed of monolithic carbon, is attached to the horizontal stabilizer by a movable titanium spar. The total composite content in the Explorer is 20 percent of empty weight.

In contrast to the Dauphin and the Explorer, Kevlar composites are primarily used in the Boeing 234. Composites are in the nose, the cabin floor, and fuel pods and their support structures, Fig. 21, (Ref. 33). The main load carrying members, like the fuel pods and fuel pod bulkheads, have hybrid Kevlar-carbon skins. A hybrid of Kevlar-glass skins are used in the cabin floor, and Kevlar skins are used in the fairings. The total composite content in the Boeing 234 is 19 percent of empty weight.

Sikorsky’s S-76 has a large number of composite airframe components. The composite horizontal stabilizer is of sandwich construction with a hybrid Kevlar-carbon skin, and cores of Nomex and aluminum honeycomb. Other airframe components, like the cockpit, upper fairings and cowlings, and fuselage skins, are made of Kevlar or a hybrid of Kevlar-carbon. The total composite content is 8.1 percent of empty weight.

Boeing’s all-composite technology demonstrator Model 360, which had a composite content of 47 percent of empty weight, extended the use of sandwich structures developed for the Boeing 234 (Ref. 27, 32, 34-35). Again Kevlar composites were widely used with limited use of carbon composites. Sandwich construction with Nomex honeycomb cores composed of 98 percent of the airframe structure. The frames, located at points of concentrated loads, and longerons were made of Kevlar composites and.

Fig. 20. Composites in the MD 900 Explorer.
Nomex honeycomb cores which were reinforced with monolithic carbon stiffeners. Large sandwich panels, up to six feet square, eliminated the need for stringers. The panels were bolted directly to the frames and longerons. The helicopter was assembled in one fixture where first the keel beam, then the frames and longerons and, lastly, the skin panels were secured. Compared to conventional metal construction, the Model 360 airframe required 83 percent fewer parts and 93 percent fewer fasteners. Boeing estimated that tooling costs were reduced by 90 percent, and the cost of fabricating and assembling was 12.5 man-hours/lb. of material used, which compares favorably to the 22 man-hours/lb. required for the prototype of the YUH-61 helicopter.

Eurocopter Deutschland’s all-composite BK.117 airframe, which flew in 1989 with the rotor system of the production BK.117 helicopter, was designed around frames and spars of monolithic carbon for high strength and stiffness. Self-stiffened sandwich panels with carbon or Kevlar skins and Nomex honeycomb core eliminated stringers, Ref. 36 and 37. Skins were made of Kevlar to improve impact resistance or of Kevlar-carbon to increase stiffness and minimize weight. In comparison to the metal BK.117 airframe, the composite airframe was 32 percent lighter and reduced parts count by 79 percent.

Westland and Agusta have substantial composite programs directed towards specific airframe components. Westland used the horizontal stabilizer of the W30-300 helicopter to compare metal, thermoset and thermoplastic technologies, Ref. 38. A carbon-epoxy was the thermoset system, and polyetheretherketone (PEEK) and polyetherimide (PEI) with carbon fiber were the thermoplastic systems. The stabilizer was constructed of sandwich panels: (0/90), skins were press-formed over a Nomex honeycomb core and bonded onto a spar and rib sub-assembly. The spars and ribs were also press-formed from unidirectional tape oriented at ±45°. The weight and cost of the thermoset stabilizer were, respectively, 30 and 24 percent less than the aluminum stabilizer. With thermoplastics, the weight savings were improved slightly and the cost was lowered by a further 24 percent. The results are given in Table 2.

**Other Components**

Composite have also been applied to the components of the drive system, the landing gear and special equipment. Several manufacturers have composite drive shafts and main rotor mast systems which either in service or in development. The challenge in composite drive shafts and masts is in the design of the attachment areas and in the damage tolerance of thin-gage walls. Attachment areas, which include splines and bearings for the mast and joints in shaft segments, are still designed with metals. Typically, the mast or drive shaft is made of composites with metal end fittings for attachment. The main rotor mast of the aft rotor system of the Boeing 234 helicopter is made of a hybrid of glass and carbon composites. Steel fittings with splines and bearing surfaces are attached with pins to the upper and lower ends of the composite mast, Ref. 39. In comparison to

**Table 2 Weights and Costs of the W30-300 Horizontal Stabilizer**

<table>
<thead>
<tr>
<th></th>
<th>Aluminum Alloy</th>
<th>Carbon-Epoxy Thermoset</th>
<th>Carbon-PEEK and PEI Thermoplastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>100%</td>
<td>70%</td>
<td>68%</td>
</tr>
<tr>
<td>Mfg Cost</td>
<td>100%</td>
<td>76%</td>
<td>44%</td>
</tr>
</tbody>
</table>
the metal mast, the composite mast was 20 percent lighter and the life increased from 1,600 to 5,000 hours.

**Potential of Composites in Helicopters**

The majority of composite applications use thermoset systems with the choice of fiber depending on the practices of the manufacturer and methods for maximizing their benefits. Thermoplastic composites have had limited application, specifically in the Westland Lynx horizontal stabilizer and the canopies of the AS 350 and AS 355 helicopters, Ref. 32.

Composites were introduced in rotor systems through the main rotor blade and in airframes through the horizontal stabilizer. The material for the rotor system is largely glass composite. Carbon and Kevlar composites are the preferred materials for airframe components. Monolithic designs are supplemented by sandwich construction with a Nomex honeycomb or foam core where additional stiffness is required. Kevlar composite is almost exclusively used for secondary structures, and to improve the damage tolerance of structures. The material form used is either cloth, tape or rovings. Prepreg cloth of composites are extensively used for cross plies or ±45° angle plies because of easy handling and low touch-labor cost. Unidirectional tape and rovings are used for higher strength and where the loading direction is predominantly longitudinal. The percentages of the different materials used in helicopters, as shown in Table 3, do not indicate the dominance of any one composite system.

The savings in weight are not entirely due to the lower specific strengths of composites but also due to innovative designs and fabrication methods. As a result, parts count, which relates directly to weight and indirectly to component and labor cost, have been reduced. In some cases, where rivets and mechanical hinges were used, the reductions have been dramatic. Estimates of the weight and cost savings for various helicopter structures, together with reduction in parts count, are given in Table 4.

The incentive that composites have provided to the development of new technology and innovative designs are best evident in the bearingless main rotor and in the tail rotor systems of the fenestron and the NOTAR. The fenestron and the NOTAR have reduced the noise level, increased operational safety and made the helicopter more environmentally friendly. Both these systems perform efficiently because composites were tailored for strength and close geometric tolerances to produce the desired anti-torque thrust. The noise level of the SA 365N-1 helicopter with the composite fenestron is about 3 dB below that of helicopters with conventional tail rotors while this reduction is doubled for the NOTAR system on the MD 520N. An improved fenestron on Eurocopter’s new EC 135 helicopter further reduces the noise level to 6 dB below the new ICAO limits, and an improved NOTAR reduces the noise level of the MD 900 to 10.2 dB below comparable ICAO limits, Ref. 40.

**Summary**

The successful and cost-effective application of composites to helicop-

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**Table 3 Percentages of Composites by Weight in Helicopters and Airframes**

<table>
<thead>
<tr>
<th>Helicopter or Airframe</th>
<th>HM/HIS Carbon</th>
<th>Glass</th>
<th>Kevlar</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA 365N</td>
<td>7</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>MD 900</td>
<td>71.6</td>
<td>27.6</td>
<td>0.8</td>
</tr>
<tr>
<td>MD 900 (Airframe)</td>
<td>97.3</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Composite BK117 (Airframe)</td>
<td>75</td>
<td>3</td>
<td>22</td>
</tr>
</tbody>
</table>

**Table 4 Potential Weight and Cost Savings**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Fewer Parts</th>
<th>Weight Savings</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuselage</td>
<td>Up to 80%</td>
<td>10 to 30%</td>
<td>0 to 5%</td>
</tr>
<tr>
<td>Tailboom</td>
<td>5 to 10%</td>
<td>15 to 20%</td>
<td>0 to 5%</td>
</tr>
<tr>
<td>Empennages</td>
<td>30 to 60%</td>
<td>20 to 30%</td>
<td>10 to 56%</td>
</tr>
<tr>
<td>Rotor Hub</td>
<td>50 to 81%</td>
<td>15 to 40%</td>
<td>40 to 60%</td>
</tr>
<tr>
<td>Main Rotor Blades</td>
<td>0%</td>
<td>0 to 5%</td>
<td>0 to 30%</td>
</tr>
<tr>
<td>Secondary Structures</td>
<td>40 to 80%</td>
<td>0 to 25%</td>
<td>25%</td>
</tr>
</tbody>
</table>

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The design and production of a component. The analytical data from material qualification and design development tests determine design allowable and characterize their mechanical response. The manufacturing data from tooling development tests establish permissible tolerances, validate qualification of the fabrication process and reduce rejections, and establish statistical NDI criteria for quality series production. Several combinations of composite materials and material forms are used in airframes to maximize their mechanical behavior and increase productivity.

As the full potential of composites develop, and aerodynamic and structural analyses codes advance, blades of the future with multiple airfoils, non-linear twist and adaptive flaps will be unrecognizable in geometry to those in service today. The challenge in the design and fabrication of structures with complex geometry will be met by the combined use of composites and automated manufacturing technology. Rotary-wing research today is aimed at developing a cost-effective, reliable and environmentally friendly helicopter.

Conclusions

Composite helicopter components have demonstrated that they are operationally superior over their metal counterparts. Structures and materials technology of advanced materials will continue to be of high interest as the demand increases for improved helicopter performance at reduced cost. The advantages in performance, range, payload and fuel consumption gained from composite application in the 1960s and 1970s have been dramatically increased through wider implementation in the 1980s and 1990s. The primary material will continue to be organic matrix composites with carbon, glass and aramid fibers. The material form will be dictated by the development of automated machinery which will qualify ease of manufacturing in the design process. The rate of increase in application will depend on the development of advanced aerodynamic codes, structural analysis tools, and automated processes for quality and high-volume production.

Acknowledgements

The author wishes to thank Mr. Carl Albrecht of the Helicopter Division of Boeing D&SG, Mr. Ed Scrags of Bell Helicopter Textron, Mr. Sam Garbo of Sikorsky Aircraft, Dr. Philippe Roesch of Eurocopter France and Mr. Jim Carver of American Eurocopter for their help and assistance.

References

10. Private Communication from Mr. Sam Garbo, Sikorsky Aircraft, 6 May 1994.
19. Sen, Joyanto K., and Drennan, Christopher C., “Design Develop-


“A Most Useful Invention: The Helicopter”

To commemorate the fiftieth anniversary of the American Helicopter Society, Evan Fridenburgh and Sikorsky Aircraft Corp. created this exciting 29-minute tape on the many and varied uses of the helicopter. Using actual footage of Sikorsky piloting the VS-300, Pescara’s Co-axial, Juan de la Cierva and his Autogiro, Piesecke in his PV-2 this tape details the beginning of the helicopter and then brings the viewer up to the present with spectacular footage of today’s rotorcraft in action. You will see the long list of impressive missions that rotorcraft perform — combat, rescue, executive transport, offshore transportation, agricultural spraying, logging, — missions being flown by rotorcraft from around the world. This informative pictorial would entertain those familiar with the industry as well as the general public who may not be aware what a truly “useful invention” the helicopter is.

This unique presentation is available to all AHS members for a mere $9.95 which includes shipping and handling (non-members $12.95.) To receive this VHS-formatted tape please contact Enid Nichols at AHS National Headquarters at (703) 684-6777 or FAX your order to 703-739-9279. Give it as a gift; show it to your children’s school; or just enjoy it as the rotorcraft enthusiast that we know you are...
AHS Snapshots

Out of the Past - Progress?

Flettner, Kellett, Kaman: What Did They Have In Common?

By John Schneider

Their common thread, of course, was the Intermeshing/Synchropter configuration. Although not a popular concept, around 400 were produced, predominantly during Charlie Kaman’s twenty years of U.S. Navy and Air Force utility production. Today, Kaman is producing the K-Max variant of the HH-43.

Flettner

Anton Flettner’s work in aeronautics began in 1905, when he was employed by the Zeppelin Company. He invented the trimming servo-tab which was initially used for Zeppelin controls but later was used on many airplanes. In the 1920’s, Flettner’s own company experimented with “Magnus Effect Rotors.” Two 50 ft. high rotating cylinders were installed on his Rotor Ship of 1924 instead of sails (Fig. 1). Although it worked, it was less than successful and nothing came of it. His first rotary wing experiments began in 1927, culminating in the 1933 tethered flights of his 100 ft. diameter “Giant” powered by two reciprocating engines and propeller units mounted mid-span on each of the two blades. Each blade was hinged in two places – at the root and at 50% outboard of the engine. It was never flown as Flettner was redirected into autogiros and helicopters for anti-submarine missions. His FL-184 Autogyro, first flown in 1935, featured cyclic pitch for the rotor. His FL-185 Heligyro, first flown in 1936, had two gyro-controlled propellers that automatically counteracted torque and added thrust for forward flight.

A German patent for a man-pedalled intermeshing helicopter had

Flettner Rotor-Ship of 1924 with 50 ft. high Magnus-Effect Rotor-Towers.

Flettner FL-265 with two-bladed rotors.
In the early 1920's, the Aero Club of Pennsylvania included a group of socially prominent "Old Friends" — Harold F. Pitcairn, C. Townsend Ludington, and W. Wallace Kellett. Wallace Kellett, an ex-American pilot in the French Air Service in WWI, was the U.S. distributor for Farman Aeroplanes. Townsend Ludington was a distributor for Curtiss and Harold Pitcairn was essentially the owner of the Pittsburg Plate Glass Co. Since Pitcairn was a pilot during the war he continued his love of flying by purchasing a diminutive Farman Sport from Kellett and eventually formed Pitcairn Aviation.

Also, by the late 1920's Ludington, along with Wallace Kellett, had established Ludington Airlines. By 1930 this airline was providing "Every Hour on the Hour" service that set records for passenger volume without subsidies. The "Old Friends" also associated with the popular aviation

been granted in 1902; and in 1938 Dr. Bennet of the Cierva Autogiro Co. brought up that concept as the solution to the size, drag, and weight of their side-by-side helicopters - the Weir W-5 and W-6 test beds. The hubs could be brought close together with an angle between the rotor axes to ensure that the blades would not foul during flight. Flettner could see how the intermeshing helicopter would be more competitive against the Focke-Wulf FW-61 Lateral Twin and he jumped at the idea! His FL-265 was the first helicopter to be built with closely intermeshing synchronized twin rotors.

Initially, Flettner used the 3-bladed rotor he was familiar with on his two previous autogyros. However, in the early flight test development a pilot had a fatal accident because the blades touched in flight. Further FL-265 development then continued with a 2-bladed rotor (Fig. 2). The follow up FL-282 was the most advanced of the German helicopters and had flown more hours with its 2-bladed system than any other German helicopter (Fig. 3). Twenty three variants of the FL-282 Kolibri were built out of the 1000 ordered for production by BMW of Munich. Although all of the jigs and tools had been prepared, Allied air attacks had severely delayed the program and production ceased in May 1945, prior to the end of WWII.

Kellett

In the early 1920's, the Aero Club of Pennsylvania included a group of socially prominent "Old Friends" — Harold F. Pitcairn, C. Townsend Ludington, and W. Wallace Kellett. Wallace Kellett, an ex-American pilot in the French Air Service in WWI, was the U.S. distributor for Farman Aeroplanes. Townsend Ludington was a distributor for Curtiss and Harold Pitcairn was essentially the owner of the Pittsburg Plate Glass Co. Since Pitcairn was a pilot during the war he continued his love of flying by purchasing a diminutive Farman Sport from Kellett and eventually formed Pitcairn Aviation.

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China National Corporation

China National Helicopter Corporation ("CNHC"), a helicopter engineering bureau for the state-owned Aviation Industries of China ("AVIC"), is a new corporate member of the American Helicopter Society. Jingdezhen-based CNHC, which combines research and manufacturing facilities, performs market research and leads international cooperation and technical exchange projects. In recent years, it has produced more than 500 Z-5 helicopter aircraft, as well as a spectrum of light to medium lift helicopters with designations Z-6, Z-7, Z-8 and Z-9. The Z-9 has a maximum gross weight of 8,000 lbs; the Z-8’s is 26,000 lbs. The parent company, AVIC, is part of a state-owned aviation manufacturing network known as the Jingdezhen group. It also manufactures under license arrangements with Eurocopter and is a risk-sharing partner on Sikorsky’s S-92 project.

Infinite Design Solutions, Inc.

AHS welcomes IDS, Inc., an industrial design firm located in Middleton, Connecticut, as a new Society member. Led by a former Bell Helicopter and Sikorsky Aircraft engineer, Donald E. Uzelac, the company specializes in CATIA applications and training, design engineering and manufacturing support, and commercial rotorcraft operations development. CATIA, which means Computer Aided Tri-dimensional Interactive Application, is an engineering software developed by Dassault Systemes of France. CATIA is now widely used for aerospace, automotive and mechanical design applications.

Alfred Gessow Rotorcraft Center

The University of Maryland has announced that its rotorcraft center will be renamed the "Alfred Gessow Rotorcraft Center" in honor of the rotorcraft industry pioneer. A gift by Gessow’s son, Andrew Jody Gessow, president of Signature Resorts, will fund the Alfred Gessow Endowed Chair in Rotorcraft Engineering at the university and provide a substantial operating endowment for the center. The gift recognizes the contributions of Professor Emeritus Alfred Gessow and his wife, Elaine Gessow.

Society’s FORUM 55 is Montreal-Bound

The 55th AHS Annual Forum & Technology Display will be held at Montreal’s Palais de Congrès in May 1999, according to a joint announcement by René Fortin, senior director of the Palais, and AHS executive director Rhett Flater. “Canada has become a major aerospace power, producing nearly one-third of the world’s helicopters,” said Flater. Two major industry firms, Bell Helicopter Canada and Pratt & Whitney Canada, are located in the suburbs of Montreal. In a related development, the City of Montreal honored AHS International Vice President (Canada and South America) Somen Chowdhury “Ambassadeur Accrédité 1997” on March 13 for his role in bringing the Society’s FORUM 55 to the city. The gala event, held at Montreal’s state-of-the-art conference center, was attended by 500 of the city’s business and political elite. Chowdhury, a Bell Helicopter design engineer at Mirabel, Canada, has led the Society’s efforts to increase membership in Canada and expand the Society’s international activities.

Honors and Recognition for AHS Members

Robert J. Gladwell, president of GKN Westland from 1983 until his retirement in July 1996, has been named to the Order of the British Empire (OBE). Gladwell served as AHS International vice president (Europe) during 1995-1996. ASTOVL program manager for the Lockheed Martin Skunk Works, Paul M. Bevilacqua, received AIAA’s F.E. Newbold Award for “contributions to V/STOL technology, including the invention and large-scale demonstration of a propulsion system for supersonic STOVL aircraft.” Robert G. Loewy, chairman of the School of Aerospace Engineering at the Georgia Institute of Technology, has received the Spirit of St. Louis Award of the American Society of Mechanical Engineers. Loewy was honored for his "pioneering contributions to rotary-wing aeroelasticity, unsteady dynam-
ics, and structural dynamics." The U.S. National Academy of Engineering has elected to membership Dr. Kenneth M. Rosen, vice-president development engineering and advanced programs at Sikorsky Aircraft Corp. for "contributions to helicopter technology and development." In 1994, Rosen received the Society's Dr. Alexander Klemm Award for notable achievement in rotary wing aeronautics. Jan Willem Stuurman, executive director of the European Helicopter Association, received a lifetime honorary membership in the Helicopter Association International.

Shawn Coyle Authors Pilot's Perspective on Helicopter Flying

AHS member and helicopter test pilot Shawn Coyle has authored "The Art and Science of Flying Helicopters," a 226 page illustrated text on helicopter piloting. Based on Coyle's experience of flying more than 40 types of helicopters ranging from the R-22 to the Mi-26, Coyle covers the fundamentals of helicopter theory, performance and flying. It progresses from a beginner's section for the novice to more advanced material, including helicopter aerodynamics, advanced performance, handling engine failures, to the design and performance of automatic flight control systems. The coverage of autorotations is detailed and comprehensive. It's available for $32.95 from Iowa State University Press, 2121 S. State Avenue, Ames, Iowa 50014-8300.

Mil Design Bureau Chief
Mark Vineberg

Dr. Mark Vladimirovich Vineberg, General Director of Russia's Mil Design Bureau, died after a brief illness on February 3, 1997. He was 59 years old. Born on July 26, 1937 in Cherkassy, he graduated from the Kaliningrad Technical Institute in 1961 and began work that year as a helicopter design engineer for Dr. Mikhail L. Mil. He earned a doctorate in engineering at the Moscow Aviation Institute in 1971 and went on to become a recognized world authority on rotary wing aviation. During his career, he authored 19 scientific publications and received patent certificates on 14 inventions relating to rotorcraft design. He was a member of the Russian Academy of Transportation, the Russian Aviation and Aeronautics Academy, and the board of the Russian Helicopter Society. In the international helicopter community, he was active as a board member of the European Rotorcraft Forum. He also served as a member of the AHS Technical Council.

Günther Reichert — Professor, Technical University of Braunschweig

German design engineer Günther Reichert, professor and chief of the Institute für Flugmechanik, Technical University of Braunschweig, died in March 1997 at the age of 65 following a brief illness. He was an important leader of the German rotorcraft industry. Together with Kurt Pfieiderer and Emil Weiland at Messerschmidt-Bolkow-Blohm (MBB), he fathered the design and development of the bearingless main rotor. He began his career as a scientific engineer at the German Society for the Study of Helicopters. From 1958 until 1983, he served at MBB rising to the position of Chief of Rotary Wing Technology and Vehicle Design. In 1983, he joined the Technical University at Braunschweig as a professor where he later became chief of aeronautics. During this time, he also served as an advisory board member to Eurocopter Deutschland and supported industry and academic collaboration in the pursuit of advanced rotorcraft studies. He was a familiar figure at international rotorcraft conferences. At the time of his death, he was acting as Chairman of the 23rd European Rotorcraft Forum to be held in Dresden in September 1997.
1997

MAY

4-6 Aviation Insurance Association 21st Annual Conference, Hyatt Regency West Shore Hotel, Tampa, FL. Contact John P. Donica, AIA, P.O. Box 2966, Redmond, WA 98073-2966, (206) 869-9522, Fax (206) 861-6499.

5-8 Offshore Technology Conference, Houston, Texas.

6-8 AIAA Global Air & Space, Hyatt Regency Crystal City, Arlington, VA. Contact Howard O’Brien, Suite 500, 1801 Alexander Bell Dr., Reston, VA 22091, (703) 264-7553, Fax (703) 264-7551.


8-9 Police Aviation ’97 Conference & Exhibition, Excelsior Hotel, London Heathrow, UK. Sponsored by Shephard Conferences & Exhibitions. Contact Kate Niven, 111 High St., Burnham, Buckinghamshire SL1 7IZ, UK, +44 (0) 1628 604764, Fax +44 (0) 1628 664075.


27-29 The First International Sea King Symposium, 12 Wing Shearwater, Shearwater Nova Scotia Canada. Contact Major Michael Vileneuve at (902) 460-1011 ext. 1142.

JUNE

2-5 ASME Turbo Expo ’97, Land, Sea & Air, Orlando, Florida. Contact Anne Buckley, (212) 705-8157, fax (212) 705-8676.

2-6 SAE Aerospace Manufacturing Technology Conference & Exhibition, Seattle, WA. Contact SAE, 400 Commonwealth Dr., Warrendale, PA 15096-0001, (412) 792-7131, Fax (412) 776-0002.

12-13 Air Ambulance ’97 Conference & Exhibition, Sofitel Hotel, Paris, France. Sponsored by Shephard Conferences & Exhibitions. Contact Kate Niven, 111 High Street, Burnham, Buckinghamshire SL1 7IZ, UK, +44 (0) 1628 604764, Fax +44 (0) 1628 664075.


16-20 Airborne Law Enforcement Annual Meeting, Nashville, TN. Contact ALEA, (918) 599-0705, Fax (918) 583-2353.


31-Aug. 6 Experimental Aircraft Association Inc. Fly-In Convention, Wittman Regional Airport,

JULY

14-18 Fundamentals of Flight Simulation, MIT, Cambridge, MA. Sponsored by the Massachusetts Institute of Technology. Contact (617) 253-2101, Fax (617) 253-8042.

16-20 Airborne Law Enforcement Annual Meeting, Nashville, TN. Contact ALEA, (918) 599-0705, Fax (918) 583-2353.


31-Aug. 6 Experimental Aircraft Association Inc. Fly-In Convention, Wittman Regional Airport,
Oshkosh, WI. Contact John Burton, Dir., Corp. Communications, EAA, P.O. Box 3086, Oshkosh, WI 54903-3086, (414) 426-4800, Fax (414) 426-6560.

AUGUST

6-10 Airshow Canada, Abbotsford, BC, Canada. Contact Airshow Canada, P.O. Box 6, Abbotsford, BC, Canada V2S 4N7, (604) 852-4600, (604) 852-3704.

11-15 Rotary Wing Technology, State College, PA. Short course sponsored by The Pennsylvania State University. Contact Judy Hall, conference planner, (814) 863-5130, Fax (814) 863-5190, e-mail: ConferenceInfo1@psu.edu

27-29 Third ARO Workshop on Smart Structures, Virginia Tech, Blacksburg, VA. Contact Prof. Harley H. Cudney, Center for Intelligent Material, Systems and Structures, Virginia Tech, 840 University City Blvd., Suite #5, Blacksburg, VA 24061-0261, (540) 231-2900, Fax (540) 231-2903, e-mail: cudney@vt.edu

SEPTEMBER


16-18 23rd European Rotorcraft Forum, TREFF Hotel Dresden, Dresden, Germany. Contact ERF Secretariat, DGLR.e.V., Godesberger Allee 70, D-53175 Bonn, Germany, (+49) 228/30 80 5-0, Fax (+49) 228/30 80 5-24.


23-25 Modern Day Marine, Marine Corps League, Quantico, VA.


OCTOBER

5-9 Association of Air Medical Services, Cincinnati, OH


8-12 Aviation Expo/China '97, China International Exhibition Center, Beijing, China. Contact Andrew Kay, Managing Director, China Promotion Ltd., Rm. 2801, Tung Wai Commercial Bldg., 109 Gloucester Rd., Wanchai, Hong Kong 2511-7427, Fax 2511-9692.


16-18 Defence Asia '97, the 7th International Defence Equipment Exhibition & Conference, Queen Sirikit National Convention Center, Bangkok, Thailand. Contact Marketing International Corp. at (703) 527-8000, Fax (703) 527-8006.


23-25 AOPA Expo '97, Marriott's Orlando World Center, Orlando, FL. Contact AOPA, 421 Aviation Way, Frederick, MD 21701, (301) 695-2052, Fax (301) 695-2375.

28-30 AHS Technical Specialists’ Meeting for Rotorcraft Acoustics and Aerodynamics, Fort Magruder Inn, Williamsburg, VA. Sponsored by the AHS Hampton Roads Chapter and the Southeast Region. Contact Dr. Thomas Brooks, Technical Chair, NASA Langley Research Center, M/S 461, Aeroacoustics Branch, FMAD, Hampton, VA 23681-0001, (757) 864-3634, Fax (757) 864-7687.

NOVEMBER

3-6 Flight Safety Foundation Inc. & IATA Annual International Aviation Safety Seminar, Washington, D.C. Contact FSE, Suite 300, 601 Madison St., Alexandria, VA 22314, (703) 739-6700, Fax (703) 739-6708.


DECEMBER

2-7 LIMA '97, Langkawi International Maritime & Aerospace Exhibition, Langkawi, Malaysia. Contact Le Protorn LIMA Sdn Bhd, Suite 804, 8th Fl., Ming Bldg, Jalan Bukit Nanas, 50250 Kuala Lumpur, Malaysia, 3-238-5857, Fax 3-238-6272.


Visit the New AHS Home Page on the World Wide Web
Point Your Browser to http://www.vtol.org

Responding to AHS members' need for cost-effective and timely communication, AHS created an Internet site as a member service. With 26 chapters worldwide including Poland, Australia, Brazil, Japan, Canada, Germany, Italy and France this site will help facilitate the exchange of important Society information.

Main sections of the home page are Headquarters; Conferences; Membership; Publications and World Wide Web Links. Special features include an on-line membership application; and an on-line survey on what users think of the site; information on all AHS and other important upcoming events; the complete AHS Forum Registration Kit and Call For Papers; Indexes on 1996 articles in Vertiflite Magazine and the Journal of the American Helicopter Society; information on joining the Helicopter Club of America; on exhibiting at FORUM 53; novelties that are available as well as details on the Igor Sikorsky Human Powered Helicopter Competition and the Student Design Competition.

The web site master is Cliff Smith of the University of Maryland and he can be reached at splash@eng.umd.edu or by phone at (301) 405-1144.

Please visit our new home page and let us know what you think.

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Shipping & Handling
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$10.00 - $19.99 $3.50
$20.00 & over $5.00

Overseas Orders
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$5.00 - $9.99 $5.50
$10.00 - $19.99 $8.50
$20.00 & over $15.00
Welcome to AHS

The new members listed below include those whose completed applications were received at AHS National Headquarters between September 30, 1996 and March 15, 1997. New members are listed by chapter affiliations with sponsors identified in parentheses.

APO/FPO
Calladine, Robert

Arizona
Adams, Alan (David H. Laananen)
Flint, Joseph W. (Gene Munson)
Fredrickson, Daphne
Kenison (USAF Retired), Lou (Gene Munson)
Pacello, Scott
Sanchez, Peter (Robert G. Cunningham)
Tesanovich, Milan D. (Eric Scheie)

Canada
Bentley, Ian R. (Ronald Bentley)
Dvornik, Janka
Gallant, Andre (Yves David)
Nitzsche, Fred

Dayton
Ankrom, Chris M.
Little, Dennis R.
McKain, Ted
Woolfner, Gene

East New England
Boedeker, Hans L.
Brock, Larry
Entin, Eileen B.
Gianonatti, Peter
Hwang, Wagner
Lee, Arthur
Maachou, Adnan
Miller, Steve
Nahatis, Harry
Pitta, Scott
Schor, Andrei
Shaknaitis, Steve
Sheikh, Waseem

Eastern Europe
Stefanov, Valery (Rhett Flater)

Empire State
Croak, Steve
Erat, Ron
Maximo, Rigoberto
Trabert, Mark J.

Europe
Bink, Jacco J.
Bradley, Roy (J. McVicar)
Cameron, CBE, John A.
Collamati, Vittorio
Gee, Alan D.
Giuseppe, Surace (Rhett Flater)
Glaskin, Max (Rhett Flater)
Sala, Mario
Wood, Alisdair E.J.

Federal City
Ackert, James E.
Aronstein, David
Baird, Kenneth A.
Bamford, Frank
Battaglia, Thomas
Beck, Corin
Bookwalter, Tim
Bowman, Theron
Boykin, Harold C.
Briciaus, Al (Stephen LaPaugh)
Capriotti, Dario
Chikosky, Matthew
Clem, Joseph D.
Dahle, John
Galway, Lou
George RN, Stephen A.
Hall, Jim
Harris, Charles S. (Dev Banerjee)
Harvey, Richard
Hirschberg, Michael J.
Hood, Adrian (Darryl Pines)
Hough, Michael A. (Pete Peduzzi)
Knapp, Pauline
Koratkar, Nikhil (A. Bernhard)
Larson, George (David S. Ferrell)
Lillard, John
Mackusick, Matt
McCaulley, Roger E. (Rhett Flater)
McKeon, Kit
Miller, Tim
Nigrel, Michael
Oertel, Robert E.
Oliver, Jonathan
Piccirillo, Al
Reddy, William D.
Robinson, Ed
Sack USN (Ret), Alvin L. (David S. Ferrell)
Scholten, Paul D.
Schultz, Joseph P. (David S. Ferrell)
Smit, Hans
Tao, Ming (J. G. Leishman)
Fordham, Keith
Hopper, Charles E.
Marrah, Bob
Partin, Belinda
Sanchez, Robert
Sareen, Ashish K.

St. Louis
Barber, David W.
Donovan, Joseph Patrick (Col.
Eugene R. Brady)
Fichter, Tom A.
Klingensmith, Jed (Patrick Brassel)
Moor, Clinton
Nance, J. L. (Patrick Brassel)
Nunelee, Steve
Rouse, Peter L. (Dr. David Peters)
Skipte, Scott (James O'Malley)

Stratford
Acunzo, Anthony C. (Kenneth L. Lauck)
Arslan, Ertegrul M. (Richard Enders)
Cakmak, Arda M. (Kenneth Lauck)
Chaseu, Scott (Gary P. Smith)
Clare, Samuel
Delaney, John
Dixson, John (Ronald G. Schlegel)
Dognin, Regis (Gary P. Smith)
Farkas, Kenneth (Ken Kendrick)
Finn, Richard C. (Paul Sikorski)
Frederick, Adam B.
Frye, Robert (Paul A. Sikorski)
Ganes, Adam (Gary P. Smith)
Gibbs, Roger (Vaughan Askue)
Goldstein, Paul B.
Gover, Donald (Harry Pember)
Gumbarecht, Todd (David Stern)
Karamahmutoglu, Murat (Kenneth Lauck)
Karaman, Bilal (Kenneth Lauck)
Karsidag, Tarkan (Kenneth Lauck)
Kasper, Charles
Keggerreis, David (Maj. Bobby Crawford)
Klingenman, David J. (Kenneth Lauck)
Kwalek, Todd (David Matuska)
List, Valerie (Gary P. Smith)
Mayo, Amy

Milin, Frank (David Matuska)
Murphy, Richard (Gary P. Smith)
Neal, Glenn (Paul A. Sikorski)
Pelletier, L. James (Ronald G. Schlegel)
Piccolo, Joseph (Kenneth Lauck)
Richard, Dianne J.
Rios, Jeffrey
Russell, Jason
Sammataro, Stephen (Kenneth Lauck)
Spak, Paul (Paul A. Sikorski)
Steponavich, James
Sweeten, Karl (Kenneth Lauck)
Uzelac, Donald E.
Varanay, Stephen (David Matuska)
Veneri, David A. (Ronald G. Schlegel)
Voegeli, Henry E.
Wierzbicki, Mark S. (Ronald G. Schlegel)

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Julian, Robert
Schneeberger, Stephen A. (David Matuska)

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