

SPACE TECHNOLOGY OPTIONS IN THE 1990s

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We've had an opportunity to review how far we've come and where we're going in the nation's space program. I guess how you view the space program might depend on who your hero was as a child. Some of us fantasized being Christopher Columbus planting a flag on a new land: Neil Armstrong and "Buzz" Aldrin got a chance to relive that moment in July 1969, planting a U.S. flag on the Moon.

Their accomplishment was in the spirit of exploration, but there are other ways of viewing space. In 1977, my daughters and young people around the world were watching the exploits of Luke Skywalker, an ace intergalactic fighter pilot. We've an entire generation of video game warriors ready to join the ranks of the Space Command as soon as we field weapons you can point with a joystick.

In 1983, President Reagan proposed a global shield to defend the world against the threat of ballistic missiles. One might compare it to Captain James Kirk's shields around the Enterprise in Star Trek.

In addition to these visions of space as a frontier to be explored, as a projection of a nation's power, or a shield to defend our countrymen — we have more traditional roles in space. Over the past two decades, we have used space systems to predict global weather, identify mineral resources, broadcast sports events, and call friends around the world.

We've been able to do so much in so little time because we have a two-track system of deploying technologies. One of these is what I call the revolutionary approach. Studies like Dr. Theodore von Karman's 1945 report called *Toward New Horizons*; Gen. Bernard Schriever's *Forecast* report of 1964; or General Skantze's recent *Project Forecast II* takes this revolutionary approach. These studies identified what was considered possible, and then looked to see what benefit these possibilities would have for Air Force missions.

The other track is the evolutionary approach. This is where we look to improve the performance of existing

systems. An example of this approach would be how we're incorporating state-of-the-art computing chips with radiation hardening techniques to upgrade the Defense Satellite Communications System, NAVSTAR Global Positioning System, and the Defense Meteorological Satellite Program.

Processes like the Military Space Systems Technology Plan, Space Architecture Study, and Space Transportation Architecture Studies keep us focused on where we're going and how today's advanced technologies will get us there. This kind of activity has been known in the business as "mission pull" — as opposed to the Forecast process, which provides a "technology push."

Forecast II provided us 70 new technologies and systems concepts that could have a high payoff as we enter the next century. More than two thousand white papers from industry, academia, and the Department of Defense were considered as we attempted to identify pervasive and enabling technologies that will advance our capabilities.

An area where we can make tremendous advances is space transportation. In this technology area, I include new launch and orbital transfer vehicles and advances in propulsion technologies.

One of these would be the Advanced Heavy Lift Vehicle. We hope to produce a large, heavy-lift launch vehicle to support routine operations in space. Our Air Force Rocket Propulsion Laboratory is developing technology for a fully reusable engine in the 600,000 to one million pounds-thrust class. The idea is to launch payloads of 80,000 to 150,000 pounds to Low Earth Orbit, and do it for a tenth the current cost-per-pound-to-orbit.

Another critical mission requirement is the need to ferry payloads between Low Earth Orbit and Geosynchronous Orbit. Today we use very expensive, one-shot systems like the Inertial Upper Stage or Payload Assist Modules to perform that mission. In the near future, we could adapt our modular XLR-132 engines for refueling capability. Looking even farther ahead, we could apply our solar thermal thruster or electric propulsion designs to take advantage of the force produced by expanding hydrogen or by using a magnetoplasma dynamic thruster.

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The Rocket Propulsion Lab is also doing exciting work in High Energy Density Propellants like tetrahydrogen or neon ozonide. These could theoretically generate a specific impulse of two to five times that of liquid hydrogen-oxygen combustion. For even more power, we can learn to use the small quantities of antiprotons being generated in cyclotrons like the one at the University of Chicago's Fermi Labs.

When an antiproton meets a proton, they annihilate one another. The result is 100 times more energetic than fusion and 100 million times more powerful than a chemical reaction. With antiproton propulsion, another Forecast II technology, the payload of the National Aerospace Plane could be raised by a factor of 10.

Another space technology area where we could use orders-of-magnitude improvements is surveillance. Even assuming Strategic Defense Initiative requirements are met, like detecting boosters and midcourse reentry vehicles, we might still be faced with the low-level air-breathing threat of cruise missiles, drones and aircraft.

The Air Force Space Technology Center is working a seven-year, \$400 million effort in infrared focal planes to advance the state of the art in solid-state physics, materials and microelectronics. We can now produce IR detector arrays that are five times more sensitive and 10 times more radiation-hard than those available just two years ago. We still have a long way to go, but IR focal planes will be our eyes in space, whether the mission is surveillance, tracking a ballistic missile, or travelling to another planet.

Alternatives to today's sensors are being developed at our Air Force Geophysics Laboratory. Geophysics Lab people are studying the signatures of ballistic missiles to see whether a rocket plume can be more accurately tracked with ultraviolet sensors. Static firings, launches and chamber tests have been done with solid and liquid boosters; and the sensor data looks promising. Understanding the natural background against which targets must be detected is also an important emphasis of the AFGL program.

An innovative concept related to surveillance that emerged from Forecast II is the Artificial Ionospheric Mirror. Over-The-Horizon radars depend on sufficient electrons in the ionosphere to refract radio waves back toward Earth. Unfortunately, the density of these electrons varies with the time of day and with solar activities. By using short pulses of extremely high frequency radio energy, Geophysics Lab hopes to produce a stable reflecting layer to enhance the performance of the OTH-B Radar.

Other AFGL programs related to Forecast II include laser radar and microwave sounders for remote sensing of the global environment. Collectively, the systems resulting from these programs will provide surveillance capabilities covering the full spectrum with greatly improved resolution.

The Forecast II process was also applied to weapons concepts. Some of them have been in the works for years. Others have just begun to be explored.

Lasers represent an area of weapons research that has always held much promise. From the first innocuous beams of a helium-neon laser to the ray that exploded the shell of a missile booster last year — we never doubted that tightly focused photons could pack a punch.

Since 1963, when our Air Force Weapons Laboratory was

formed, we've demonstrated the ability to produce powerful laser beams and to aim those beams accurately to destroy targets. We've demonstrated the vulnerability of various aerospace materials and systems to laser light; and we have identified techniques to overcome the difficulties of building large laser systems and propagating laser beams through the atmosphere.

You've heard of our successes in carbon dioxide and hydrogen fluoride high energy lasers. Let me assure you that we have only begun to realize the potential of other laser techniques. Last year, for instance, the Weapons Lab demonstrated a solid-state adaptive optics technique to correct for aberrations in laser beams. In another experiment, two iodine lasers were coupled and essentially acted as one. Duplicating this achievement at higher powers would demonstrate that we can scale-up this technology for an intense beam that propagates well.

The result of all this is a technology that could be used in a surveillance mode or in a pointing and focusing mode for a ground-based or space-based laser. Other applications would include laser imaging and secure communications.

As you well know, there are other portions of the electromagnetic spectrum with possible weapons applications. One of these is in the one-to-40 gigahertz range, called high frequency microwaves. By exceeding the space charge limiting current in an electron beam generator, a virtual cathode oscillator is produced that converts the energy of the electron beam into microwave energy.

The Weapons Lab is also working on directed X-rays and plasmas of interest to Air Force planners.

That's how we use revolution to our advantage. We let the technology base grow; and as it grows, we learn how to expand it even further. Now let me discuss our other approach to advancing technologies — the top-down, mission pull, evolutionary approach.

The classic example of this process at work in our Space Technology Center is the Military Space Systems Technology Plan. Through this systematized analysis of our missions and technologies, we identify the critical technologies and investment strategies that will produce the capabilities we need in coming decades.

The MSSTP, the forerunner to our expanding Space Technology Data Base, began with a review of national space policy. Another consideration was the planning of investment and management strategies that had gone into the Air Force and Systems Command space plans. Present and projected threat environments were evaluated; and plans were identified to meet those threats.

Having established candidate missions and what our goals and mission requirements were, we began to look at space systems concepts. Space Command had already done a Space Systems Architecture Study, so we examined their concepts that could result in a high-payoff architecture in the near future. We also looked for some overlap from the technology concepts that were being considered under the Strategic Defense Initiative.

A Space-Based Radar/Infrared system was proposed to detect enemy ships, aircraft and other items of interest.

Having identified systems concepts, we sat down with industry to look at technologies in development and forecast

how soon they could contribute to our space systems.

By looking at how technology trends could exceed, meet, or fall short of our expectations — we were able to identify technology issues to be resolved. Then we came up with road maps to get past the critical technology obstacles.

Some of our technology issues are things like Signal Processing. That is, our ability to turn high capability sensor data streams into meaningful information.

Autonomous satellite maintenance involves routine thermal control, battery charging and reconditioning, solar array pointing and correction of on-board faults in computing.

Survivability; Communications; Electro-optics; Guidance, Navigation, and Control; and Environmental effects are some other disciplines where we identified issues which affected our systems concepts to varying degrees. The key to each step of the Military Space Systems Technology Plan and the Space Technology Data Base is that they look like upside-down trees. Everything branches out from architecture and mission decisions down to the concepts, supporting technologies, budget priorities and the plans that resulted. You can easily see the connections.

The MSSTP was a six-volume study, with the final volume being our Space Technology Plan. At this point, we've loaded information on a number of space concepts and technologies into the Space Technology Data Base. Eventually, we'll provide planners and designers a data base with which they can easily find and update information on any of our emerging space concepts.

Obviously, there are more applications for the evolutionary, top-down approach than just Air Force systems. The Strategic Defense Initiative, for example, would see several areas of overlap in an operational architecture.

The surveillance mission is similar. Defense applications are similar. Communications and Navigation requirements are similar, just as they are for space computing.

Active discrimination needs are also similar. Whether we do it in the name of early warning, or surveillance, or tracking and pointing — somebody is going to do this job. We would need particle beams, infrared or ultraviolet lasers, microwaves, or radar to sweep space; and we would use sensors to recognize a target against the natural background of space and Earth.

Whether we design the space architecture in the name of SDI, the Air Force, or the U.S. Space Command — the mission and the technologies are virtually the same, and so are the technology and funding issues.

So it is with a space transportation architecture. We know we have to have a system that's cheaper than the Shuttle to run, with the capability of delivering loads of many sizes to orbits of various altitudes and configurations.

To get a handle on this challenge, we asked the folks at Boeing, General Dynamics, Martin-Marietta and Rockwell to look at the mission models prepared by the Air Force, SDIO and NASA, and to identify what space transportation architectures would fulfill future requirements.

Additionally, they looked at enabling technologies and identified the risks and payoffs of bringing those technologies to fruition. An example of a technology the experts say we need is an advanced orbital transfer vehicle that economizes on its fuel consumption by using an aerobrake on the return trip. By one estimate, we'd recover the acquisition cost of the aerobrake technology in the first four years of service.

So the equation gets very complicated at this point. We can save on launch costs if we can learn to refuel and maintain advanced Orbital Transfer Vehicles on orbit. This in turn, causes us to look at the capabilities and limitations of astronauts or robots in space; the advantages of standardized spacecraft configurations; and a host of trade-offs between costs, capabilities and timelines.

By doing our homework a decade or two in advance, we're ensuring the technologies most critical to the process are going to come in on time to marry up and launch our next generation of space systems. By having identified the pervasive technologies, such as radiation-hardened microchips, we can begin to make existing space systems more effective and less expensive to launch.

By waging revolution and evolution simultaneously, we are creating options for the 1990s and beyond. Inherent in those options, however, are some hard decisions. A distributed space array radar could eliminate or reduce the need for the Air Force's AWACS or the Navy's Hawkeye aircraft.

A Reusable Orbital Transfer Vehicle could eliminate the need for today's Payload Assist Module. In the near future, our Forecast II budgets, our SDI budgets, our Air Force space budgets and our NASA budgets are going to face increasing competition with things like manpower levels, war reserve materials, strategic modernization, and the plans for space-based materials production.

The decisions we make in an environment of fiscal restraint will probably depend on our view of the world. Some of us will want to plant flags on new lands. Others will want to extend the national interest into a Fourth Realm — right after land, sea and air. I believe all would opt for a safer world no longer threatened by nuclear weapons.

At the Air Force Space Technology Center, we've opted for the eclectic approach. We'll wage continued technological revolution and evolution for whatever vision our nation's people have in mind — whether it's exploration, the national interest, or greater safety.

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