THE POTENTIAL IMPACT OF THE SPACE SHUTTLE ON SPACE BENEFITS TO MANKIND

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Introduction

The Space Age may be divided into three general decades:

- The sixties, during which the initial steps of space exploration were undertaken.
- The seventies, when it can be anticipated that the successful explorations of the preceding decade will be developed into practical applications.
- The eighties, when developed capabilities will be put to extensive use.

The benefits to mankind are beginning to appear in ever-increasing amounts (Fig. 1):

- During the sixties, these benefits generally took the form of space technology applied to uses on earth; e.g., materials, electronic components, computers.
- During the current decade, these benefits will increase to include systems operating from space; e.g., weather prediction, communications.
- During the next decade, these benefits will further increase because of new applications (e.g., earth resources and navigation) and the ability to conduct more space operations (for a fixed budget) through the reduced costs of both transportation and payloads arising from development of the Space Shuttle.

This discussion will concentrate on Shuttle-induced benefits.

Near-Earth Space. Space can be conveniently divided into three areas (Fig. 2):

1. Escape, which includes the lunar and planetary areas; that area beyond the influence of the earth's gravitational field.

2. Synchronous is that altitude at which a satellite will remain above a fixed point on the earth.

3. Near-earth is a region below the inner Van Allen belt (~ 500 n. mi.). This area is generally further limited to about 80 to 270 n. mi., the former established by premature orbit decay, the latter by excessive performance requirements.

Typical payload types and their relative status are also shown for each space area.

Near-earth missions are directly supported by the Shuttle. Operational areas for both the Space Shuttle and Tug are noted on the accompanying chart. Synchronous and escape missions require both a Shuttle and a Tug: the former to place the Tug and payload in near-earth orbit, the latter to transfer the payload to the final orbit.

Space Mission Characteristics. Figure 3 indicates the weight of payloads placed in near-earth (80 to 270 n. mi.) orbit and into synchronous and escape orbits. For the latter payloads, an appropriate stage (Tug) is required for transfer from near-earth orbit to the final payload destination. Typical weights for this stage are also shown. When stage weight is added to that of the payload, an equivalent weight to near-earth orbit can be determined. These results are noted in the last graph and form the basis for the Space Shuttle payload requirements. The difference in Shuttle performance required for the two missions is accommodated by the variation in the launch azimuth required to support each mission. Synchronous and escape missions are generally launched in an easterly direction and are thereby aided by the earth's rotation.

Thus, a Shuttle with the ability to launch 40 000-lb payloads, in support of near-earth missions, and 65 000-lb payloads, in support of synchronous/escape missions, will have the capability to capture the forecast average of 30 near-earth and 20 synchronous/escape missions per year.

Current United States Space Launch Systems Inventory. The current U.S. inventory of space launch systems accommodates a wide range of payload weights to near-earth orbit, increasing (Fig. 4, from left to right) from about 300 lb for the Scout to about 250 000 lb for the Saturn V. With the continuing reduction in the number of payloads launched each year, maintaining this extensive inventory is becoming increasingly inefficient.

Future Space Launch System Inventory. Development of the Space Shuttle in accordance with the capabilities previously described would allow the U.S. space launch system inventory to consist of only the Scout vehicle and the Shuttle (Fig. 5). This inventory retains the capabilities of the current space launch system fleet and, in addition, affords the following desirable characteristics:

- Economic for both low and high launch rates
- New modes of operation, resulting in the potential for significant payload cost reductions
- A high degree of standardization, leading to reduced costs for payload integration, flight operations, and personnel support.

Mission Profile

Significant elements of the Space Shuttle mission profile are ground operations, launch, and staging of the two Shuttle vehicles (Fig. 6).

After staging, the first stage (booster) returns to the launch area, while the second stage (orbiter) attains the prescribed insertion orbit after a series of orbital maneuvers. The orbiter then delivers and/or retrieves its payload, enters the atmosphere, acquires the landing site, and completes the approach and landing.

Safing operations are completed on each stage at the landing area, preparatory to the turnaround cycle ground operations. After payload installation in the orbiter, the orbiter is mated with the booster, and the mated system is made operationally ready and transported to the launch area for a new mission.

This sequence of events is described in more detail in the following pages, starting with servicing the vehicle in the Maintenance and Refurbishment (M&R) facility.

Space Shuttle Vehicles in M&R Facility. The booster and orbiter are shown in Figure 7 during maintenance operations within the M&R facility, which provides a protected environment for performing turnaround maintenance, premating, and erection tasks. M&R includes the area for mating and erecting the vehicles. Scheduled (time- or event-oriented) maintenance will be minimized, and airline-type condition monitoring techniques will be maximized to provide the rapid, reliable turnaround cycle required by the Space Shuttle program.

Erection, Checkout, and Preflight Handling Sequence. Upon completion of turnaround maintenance activities in the M& R area, the booster and orbiter are ready for mating activities and subsequent prelaunch activities. These activities account for approximately 70 percent of the ground turnaround elapsed time. Of this period, erecting, mating, transporting, and connection to the launch pad require approximately 80 percent of the time. Establishment of a minimum time interval of the vehicle on the launch pad is governed by:

- Rescue contingencies
- Accomplishment of the high rate of operational launches with existing facilities.

The vehicle and support equipment design (plus the planned sequence of operations) will contribute to the achievement of a minimum on-stand time for the vehicle.

Vehicle Erection and Mating in the High Bay. Erection and mating operations are accomplished in the existing high-bay area of the Vertical Assembly Building:

- The booster is hoisted first, and installed on the mobile launcher with the upper surface of the booster facing away from the launcher umbilical tower.

- The orbiter is then hoisted and placed on the upper surface of the booster.

This orientation and sequence of operations will allow booster erection in advance of the orbiter and provide better clearance for the mating operation. These aspects promote flexible scheduling and rapid mating operations.

Vehicle Transport to Launch Pad. The Space Shuttle is mated on the mobile launcher, and moved to the launch pad on the existing crawler-transporter. The crawler-transporter engages the mobile launcher in the Vertical Assembly Building, moves the launcher to the launch pad, and then disengages from the launcher. The transport task will require approximately 10 hours.

This transportation method was selected after studying various other horizontal and vertical techniques. The selected method allows use of existing equipment that will support the turnaround requirements and significantly reduce program cost.

Terminal Countdown. As currently planned, the terminal countdown is a brief evaluation of the active functional paths required for the mission. The prime control will be onboard, with ground personnel providing expertise as may be required. A minimum number of monitor consoles and positions will be used. These measures reflect a marked contrast to the large numbers of support personnel and long countdown times required for present manned launch vehicles.

Board Personnel. It will be possible to enjoy great freedom of movement in the "shirtsleeve" environment of the passenger/crew compartment. In this environment, bulky spacesuit equipment, with its complex connections, is eliminated. Because the crew is not encumbered by this equipment, a rapid boarding (or deboarding) process is possible with simplified closeup tasks.

Mated Shuttle Vehicle at Liftoff. The Shuttle vehicle, with main engines ignited, is shown at about the time of liftoff from the pad in Figure 8. After liftoff, the vehicle will rise vertically to a point approximately 100 ft above the launcher umbilical tower. At this point, first the roll then pitch programs will be initiated to achieve the desired trajectory. The guidance system will be an autonomous onboard system.

Mated Shuttle Vehicle During Boost. Loads induced during mated flight will be reduced through the use of a load-relief flight control program. Under normal conditions, flight crew tasks are of a monitoring nature during this phase of flight. The mated Shuttle vehicle follows a preprogrammed flight path. Safe abort and landing are possible, if required, during this phase of the flight.

Space Shuttle at Staging. The booster and the orbiter are shown in Figure 9 at staging, with the orbiter continuing on its mission and the booster preparing to descend. The separation sequence is initiated by appropriate sensors monitoring booster propellant levels. To separate the vehicles, combined booster and orbiter thrust is employed through a mechanical leverage system.

The orbiter will continue, under thrust, to its defined orbit, while the booster will initiate a turning descent for return to the launch base (Fig. 10). The booster will enter the atmosphere in an entry mode that will attain a maximum of 4 g for a short time.

This concept of separation was selected after a study of several methods, because it provides excellent separation characteristics at normal staging, as well as rapid separation any time during mated flight.

Booster During Cruiseback to Launch Site. Following separation from the orbiter and atmospheric entry, the booster uses its airbreathing engines to cruise back to the launch site at an altitude of approximately 10 000 ft (Fig. 11). Federal Aviation Administration (FAA) contact and control are anticipated for the flyback operation. Takeoff and cruise capability also enables the booster to make normal cross-country ferry flights.

Booster at Landing. The booster will return to the runway at the launch site approximately 2 hours after launch (Fig. 12). Landing is similar to that of a conventional jet aircraft. After landing rollout, the booster will taxi to the safing area. Selection of the launch site as the primary return site for the booster permits sharing facilities.

Should an alternative landing site be required because of an abort or to maximize performance capability, any conventional 10 000-ft runway, with standard landing aids, will serve as a landing site.

Booster in the Safing Area. After taxi from the runway area, the booster will be made safe for subsequent operations (Fig. 13). Any residual main engine, power system, or attitude control propulsion system propellants and resulting evaporated gases will be drained and purged to an inert level so that turnaround maintenance can be accomplished in a nonrestricted, nonexplosive environment in the maintenance building.

Orbiter Unloading Payload at Space Station. During this mission phase, the orbiter is the active element in transferring the payload. Orbit maneuvering is provided by the orbiter maneuvering system. The orbiter cargo-handling and stabilization control will be easily accomplished. After the Space Station/orbiter combination is configured and stabilized, cooperative procedures will be implemented for cargo transfer activities (Fig. 14).

Orbiter During Entry. Orbiter entry (Fig. 15) will be accomplished at a velocity significantly higher than that of the booster, thereby requiring a thermal protection system that will survive extreme entry heating. Entry will normally be accomplished in the vicinity of the landing site which, for nominal conditions, will be the launch site.

The orbiter thermal protection system is designed to provide the capability for 1100 n. mi. of aerodynamic crossrange.

Orbiter at Landing. Landing characteristics of the orbiter are comparable to current high-performance aircraft (Fig. 16). Unlike the booster, the orbiter is capable of landing either with or without airbreathing engines. Consequently, use of airbreathing engines will be dictated by mission requirements that, in turn, will depend upon payload weight, landing site, ferry requirements, etc.

Upon completion of the landing phase, the orbiter undergoes a safing procedure similar to that conducted upon the booster vehicle.

Capabilities

Apportionment of stage sizes to the two-stage launch vehicles (Fig. 17) permits satisfaction of a variety of missions in the most cost-effective manner.

The ability to transport or retrieve a variety of orbital payloads affords the flexibility to support all anticipated space applications with the same basic launch vehicle (Fig. 18).

The ability to provide service to payloads and/or personnel on orbit extends the previously noted capability to the space environment (Fig. 19). Space rescue is one such extended capability; another is economical Space Shuttle Station logistic resupply.

System reusability (Fig. 20) affords both low recurring transportation costs and the ability to amortize Shuttle development costs within the operational life of the program. Additional capabilities include:

- Development of earth-oriented equipment through sortie mode flights
- Reduction in losses due to abort or satellite failure
- On-orbit scientist participation.

Cost Effectiveness

Reducing the Cost of Space Operations. The Space Shuttle has a design goal of reducing by an order of magnitude the cost of transporting payloads, both manned and unmanned, to low earth orbit. Even greater reductions are possible in placing satellites into synchronous and other high-energy orbits. These goals can be achieved with the Shuttle vehicle currently defined (Fig. 21).

Additional savings are also possible because of the manner in which the Shuttle operates. The intact abort capability (separate and safe recovery of both orbiter and booster after malfunction), for example, provided by the Shuttle will further reduce the cost of payload losses because of launch vehicle failures will no longer be experienced. Also, the ability to return payloads should reduce "infant mortality" losses to essentially the cost of a second Shuttle launch. Payload design may take further advantage of this ability to allow periodic refurbishment or upgrading of failed or obsolescent payloads.

The value of diagnostic study of prematurely failed space payloads should not only prevent recurrence of such failures, but should afford the payload designer a better understanding of operational margins of safety. Finally, the ability to guarantee placement of time-critical payloads has a significant but difficult to quantify value.

The benign environment of the Shuttle cargo bay (e.g., low g-loads, an absence of shock loads induced by pyrotechnics, and the ability to continuously support the payload along its length) will result in substantial reductions in the cost of payload design, development, qualification, and production. Such features, coupled with relaxed payload weight and volume restrictions (for all but the most demanding payloads), should make it possible to design payloads in a more economic manner.

The ability to perform experiments in space in an economic manner is yet another Shuttle-derived benefit. To date, many desirable experiments have been defined, but their implementation has been impeded by the high cost of transporting the payload to orbit, the cost of man-rating the launch vehicle for manned payloads, or the cost of fabricating the payload itself. In each area, the Shuttle offers significant benefits. It requires no additional man-rating, since the orbiter element of the Shuttle may be used as the experiment base for periods up to 30 days. Thus, the need to develop a specific payload vehicle can, in many cases, be restricted to the development of experiment-peculiar instrumentation. Indeed, because of the Shuttle environment and the availability, if desired, of supporting technicians on orbit, many space experiments may be conducted with laboratory-quality equipment rather than the more costly space-qualified equipment.

Space Shuttle: Fundamental to Future Space Development Activities - I. As currently conceived, the Shuttle is the keystone to future space development activities. In addition to the payload implications previously noted, the Space Station (Fig. 22), Space Tug (Fig. 23), and Research & Applications Modules (RAM) (Fig. 24) depend upon the Shuttle for transport to orbit, support while in orbit, and, when appropriate, return to earth. The ability to incorporate these programs, in an orderly development, depends on the Space Shuttle.

In view of the sequential dependency of the other advanced space program elements, the Shuttle is, in effect, the only viable early program start. Indeed, much of current space program planning is predicated upon early development of the Space Shuttle; e.g., future Space Stations are based on extended orbital stay times for both technical and economic reasons, and such stay times are practical only with economic logistic resupply.

Space Shuttle: Fundamental to Future Space Development Activities - II. From the frame of reference of the Space Shuttle, there need be no dependent commitment to develop any of these other systems; however, their development could be a natural follow-on to the basic Shuttle program. Accordingly, it is at the discretion of the President and Congress when and if these activities are initiated. But the ability to incorporate them into an orderly development is available so long as the Shuttle vehicle is present.

Impact Upon Technological Superiority

Current Space Program. Principal features of the current space program (Fig. 25) are, briefly:

1. A reduction in funding from the peak achieved in the late sixties

2. An accelerating-reduction in employment featuring:

   a. Declining numbers of scientists/engineers employed

   b. Those who leave do not wish to return

   c. Rapid "aging" of engineers and scientists employed in the aerospace industry

   d. Declining numbers of engineers and scientists enrolled in universities

   e. Disenchantment of young people with technology and aerospace.

3. Reduction in the annual launch rate and pounds of payload placed in orbit from the peak achieved in the late sixties

4. Essentially, completion of technological advances arising from the current space program. (Note, this does not mean completion of such advances to new products and/or the "reduction to practice" of such advances.)

Without a reversal of these trends, the U.S. may be compromising its ability to meet future national goals.

National Goals. A persuasive argument can be made that an early Space Shuttle contract go-ahead is a reasonable and prudent step that would contribute significantly to attainment of those national goals that almost everyone considers to be fundamental to a healthy and vigorous national posture.

As a democratic and dynamic society, we in the U.S. have many and changing national goals. Although there is wide disagreement as to relative priorities among the various national goals, almost everyone will agree that three are very high on any rational priority list (Fig. 26):

1. Maintenance of National Security — Our national security forces must have two basic characteristics:

a. Quality essentially equal to, or superior to, the forces being countered.

b. Timely deployment consistent with the attainment of substantial operational capability by the forces being countered. (Too little [in quality] or too late [in deployment] is not acceptable. Maintenance of national security is contingent upon the ability [not necessarily the act] to deploy quickly quality weapon systems which, in turn, requires maintenance of a superior technological capability.)

2. Improvement of Economic Vitality — In a highly industrialized society, such as ours, the creation of new job opportunities is heavily dependent on the application of the fruits of a continuously expanding technological base to develop new products. Expanding technological capability is thus a prerequisite to the creation of the job opportunities that are essential to maintaining and improving economic security. If the nation is to improve its economic vitality, it must maintain a favorable balance of trade in the face of increasing competition from nations with rapidly expanding industrial and technological capabilities. Over the long term, this can be achieved only if technological superiority is maintained.

3. Enhancement of the "Quality of Life."

Enhancement of the "Quality of Life." If we are secure, and if our economy operates efficiently, the diversity of technological innovations that flow from maintenance of technological superiority will regularly continue to enhance our quality of life. In advancing the quality of life, our nation must cope with many problems, among them:

1. Providing opportunities for all citizens to obtain:

a. Education consistent with their abilities

b. Gainful employment

c. Security from poverty

d. High-quality medical care

e. Recreational and cultural opportunities.

2. Reduction in crime

3. Control of environmental pollution

4. Relief from the congestion and frustrations that plague both our urban communities and our urban commuters (Fig. 26).

Expanding technological capability does not, in itself, ensure that these critical problems will be resolved. These problems can be resolved only by a combination of a national commitment to resolve them, coupled with the technological innovations required to resolve them, which can flow only from an expanding technological capability.

Requirement for Technological Superiority. It seems plain that nourishment of our technological base to ensure an expanding technological capability is essential to the achievement of such high-priority national goals as national security, improved economic vitality, and enhancement of our quality of life (Fig. 27). It follows, therefore, that commitment of resources to programs that focus around the sustenance and enrichment of our technological base is not, as some argue, "Counter-productive to the new ranking of national priorities," but rather is mandatory if the desired national goals are to be attained. Thus, the maintenance of technological superiority should have high national priority, regardless of the current reevaluation of the rankings of natural goals. Technological superiority is a vital prerequisite to the attainment of almost all national goals.

Elements of Technical Superiority. Technical superiority is achievable through the complex and interrelated working of four categories of activities (Fig. 27):

1. Conducting exploratory research in the interest of advancing technical superiority

2. Developing and "reducing to practice" state-of-the-art technology

3. Improving and extending present technical skills

4. Sharpening and refurbishing applied technical tools.

The end products of the beneficial coordination of these activities are the hardware, processess, tools, and skills that comprise "Technical Superiority."

Maintenance of Technological Superiority. Maintaining technological superiority depends upon the continuing health of five distinct but related areas (Fig. 28):

1. Basic research across a broad front

2. Applied research in selected areas

3. "New blood" in the form of young scientists and engineers

4. Major, technically challenging development programs of national scope

5. Multidisciplinary management/scientific/engineering/production teams that integrate and motivate government, university, and industrial organizations.

Justifications for the first two areas will not be repeated here, since they are familiar and not directly related to a case for Space Shuttle. The latter three items are relevant and will be treated in some detail in the following pages.

Availability of Engineers and Scientists for Future "Cutting Edge" Development Programs. One of the five elements essential to maintaining technological superiority is the ability to continually attract "new blood" — young scientists and engineers — to the development programs that form the "cutting edge." In the current environment, both opportunities for the attractions for young scientists and engineers to join active advanced development teams have vanished. As teams undergo forced reductions, a disproportionately high percentage of young engineers and scientists are among those laid off.

This combination of essentially a zero inflow and a disproportionately high outflow of young engineers and scientists has resulted in the unfavorable trend that the average age of engineers and scientists employed in the aerospace industry is increasing by more than 1 year per calendar year.

The lack of opportunity, coupled with the disenchantment of young people with technology and, in particular, with the aerospace industry, has resulted in another unfavorable trend: reduction in science and engineering and enrollment in our colleges and universities, even as total enrollment continues to increase. Enrollment of full-time students in engineering schools, for instance, decreased by 9500 during 1969 and 1970, and master's degree candidates have decreased by 18 percent since 1968. All signs indicate that the production of scientists and engineers in the Soviet Union is continuing to increase.

A large proportion of scientists and engineers who have left the aerospace field has been irreversibly lost. It has been our experience that the majority of such engineers will not consider rehire (even if offered large salary increases), because they seek more certain futures in stable fields that are free of political reevaluation. There is a sense of anxiety about working in a career area that is strongly impacted by public whim or by a new-found popular disfavor with technology.

Aerospace industry engineering and scientific employment has declined from a peak of 223 000 in 1963, to a current level of 175 000, and the slope is still depressingly steep downward. The projections indicate that this trend will continue, although, at a slower rate, even if new national programs are initiated in the immediate future.

The human resources that should be available to future integrated and multidisciplinary development teams are in jeopardy due to the five factors discussed briefly above (Fig. 29):

1. Declining number of engineers and scientists employed in the aerospace industry

2. Surprisingly strong determination of those who have left, never to return

3. Rapid "aging" of engineers and scientists employed in the aerospace industry

4. Declining enrollment of science and engineering students

5. Disenchnatment of young people with technology — particularly with the aerospace industry.

As a result, the nation may lack the human resources required to maintain our technological level in the seventies, and may find itself irreparably behind the power curve in the decade of the eighties. Implementation of a single major program development will not, by itself, correct this bleak situation, but inauguration of the Shuttle will be a step in the right direction.

Major Programs as the "Cutting Edge" of Technological Advancement. New programs that serve as the foci that forge the "cutting edge" are now urgently required to replace the Intercontinental Ballistic Missile (ICBM) and the Apollo programs. It will not be as easy to rally congressional and public support for new programs in the current environment. The direct goals of a program, such as Space Shuttle, will not be as apparent or considered as critical as were those of the ICBM or Apollo. The indirect benefits — serving as the "cutting edge," which are equally important, indeed, critical to the maintenance of national technological capability — are not generally appreciated or well understood by the American public. Although the difficulties in advocating such programs are today more severe, the critical necessity for such "cutting edge" programs that permit the momentum of technological advance to continue is no less real.

It is essential that Congress and the public be afforded a better understanding of three aspects of technology (Fig. 30):

1. The role of technology as the progenitor of major programs

2. The long lead times required to reach the technical "payoff"

3. The difficulties involved in distributing the resources required to balance the technical effort.

Integrating Influence of "Cutting Edge" Programs. Characteristically, our nation has had a high degree of success in bringing together the knowledge (gathered from basic research and applied research) and the people (scientific, engineering, and technical personnel organized in multidisciplinary teams) to improve our technical and economic capability; these resources have been applied in a major program toward the end of obtaining a new, better, or less expensive product. But important byproducts of these efforts have been:

1. Stimulation of new concepts

2. Advances made in technology — the state of the art

3. Translation of scientific information into engineering and technical skills

4. Sharpening and refurbishing operating tools, skills, and processes (Fig. 31).

Major "Cutting Edge" Programs. In our generation, the U.S. has made a dramatic advance in its technological capability. The momentum of this advance has depended upon the "cutting edge" provided by major national programs that focused advanced management, scientific, engineering, and production talents on achieving specific capabilities at specified times (Fig. 32).

In World War II, for example, high-performance aircraft, radar, the atomic bomb, and other specific weapon systems served as the foci and provided the catalyst for a surge in technological capabilities. These programs were readily supported by Congress and the American public, not because they advanced technological capabilities, but because they were considered essential to prosecuting the war effort and, therefore, essential to national survival.

In the cold war period, the hydrogen bomb, ICBM, and nuclear submarine programs served as similar foci and forged the "cutting edge" of continuing growth in technological capability. These programs were also readily supported by Congress and the American people. Again, not because they forged the cutting edge, but because they were considered essential to national defense.

Later, the response to Sputnik, culminating in the Apollo program, increased our awareness of the need to sharpen the "cutting edge" and ensured the momentum that maintained our technological superiority. This effort was also readily supported by the Congress and the American public as a result of the shock of Sputnik and the call of President Kennedy to a great adventure: "to be the first people to walk on the moon."

Thus, during our generation, major cutting-edge programs have found support — but this massive support has been forthcoming for reasons other than the assurance of national technological leadership.

Required Program Features. The required program features enumerated in Figure 33 serve as a checklist to test the suitability of candidate programs. Briefly, these features are:

1. Technology advance to support "technical superiority" through the interrelated working of the four noted activities

2. Capability of a near-term program start

3. Maintenance of and, perhaps, modest increase in engineering work force

4. Ability to achieve a reasonable rate of return through implementation of a major program that can serve as the "cutting edge" that permits the momentum of technological advance to continue

5. Ability, if desired, to expand to other programs in a controlled and predefinable manner

6. Ability, if desired, to stretch program development in an efficient manner to conform to currently unforeseen funding limitations

7. Ability to include international participation in an orderly and mutually satisfactory manner.

Required Results of New "Cutting Edge" Programs. "Cutting edge" programs must be of a magnitude (in terms of resources committed), urgency, and level of technical difficulty that the Nation will recognize the critical contribution that the program will make and will be steadfast in giving the program its support. The salient requirements of such a program are noted in Figure 34.

Space Shuttle: Impact on National Technical Superiority. Space Shuttle can and should serve as the keystone of our future national space program. This belief is based on Shuttle's ability to serve as the keystone for future space development activities.

The Space Shuttle program is well suited to replace Apollo as the sharp "cutting edge" required to maintain national technological superiority. It will serve as a focus of and catalyst for advanced technology efforts in a variety of fields that have tremendous economic potential; e.g., high-temperature materials, lightweight structures, automatic checkout for complex systems, and hypersonic aerodynamics.

In addition, operational capabilities of the developed system will: (1) greatly increase our flexibility to perform space operations, (2) increase our opportunities to apply space systems to the direct benefit of man, and (3) greatly improve the economics of space operations.

In summary, the Space Shuttle program is ready to enter the development phase, will result in operational capabilities of great direct benefit to the nation, and, more important, can serve as the "cutting edge" of expanding technological capability. Without a near-term start of a major program, such as the Space Shuttle, the "cutting edge" that was keen during the Apollo development program will continue to grow dull, and soon, with a deceleration of technological advance, the Nation will lose its technological superiority.

Impact Upon National Economics

Comparative Impact of Three Environment Programs. A Space Shuttle program will generate a higher level of indirect purchases (and therefore total purchases) than would an equivalent outlay for consumer spending, and a significantly higher level of indirect purchases than would the same dollar outlay for a residential housing construction program (Fig. 36). The total direct purchases attributable to each of the three programs were aggregated into eight industry groups. Two significant points are conveyed by these data:

1. The impact of the Space Shuttle will pervade the total economy into each industry group.

2. The Space Shuttle is the only alternative considered that will stimulate the aerospace industry, where there, currently, is a very high level of unemployment among highly skilled workers, scientists, and engineers.

Thus, of the three programs compared, the greatest impact, from the standpoint of total production, would result from the Shuttle program.

It is interesting to note that high-technology industries are the areas primarily affected by the

Shuttle program, whereas relatively low-technology industries are primarily impacted by the other programs. From this, one can discern that solutions to the high unemployment problem found among highly trained engineers, scientists, and skilled technicians would most likely be found in the Shuttle program.

The Space Shuttle program would also tend to favorably impact the U.S. balance-of-trade problem, since the program would require fewer imports than would be required for residential housing construction or consumer spending. Perhaps of equal significance is the fact that since the Shuttle program would stimulate high technology industries, it would ipso facto provide a greater stimulus to high-technology exports. This is of vital importance since the U.S. depends on high-technology export to maintain a favorable balance of trade. It is also important to note that, based on each industry's ratio of exports to total 1970 production, the Shuttle program would induce three times more total exports than the other two programs.

National Economic Benefits of Space Shuttle Program. In summary, the Space Shuttle program would have a favorable impact upon the U.S. economy in the following ways (Fig. 37):

1. The approximately $ 9.5 billion cost to the U.S. Government would stimulate about $ 20 billion of domestic production.

2. Many jobs would be created: more than 400 000 man-years in the aerospace industry and more than 280 000 man-years in nonaerospace industries. The current unemployment problem in the aerospace industry would be partially alleviated.

3. The U.S. balance-of-trade picture would be improved. Space Shuttle would require fewer imports than would a residential housing construction program or increased consumer spending of comparable size. Also, based upon the historical ratios of exports to total domestic production, the Space Shuttle program would induce more total exports than the other programs examined. More important, the Shuttle will simulate those high-technology industries that have been the most significant source of U.S. exports in recent years.

Conclusion

The Space Shuttle program, as currently defined, will:

- Satisfy national space transportation requirements at reduced costs
- Permit additional savings to be made to payload development and operation costs

which, in turn, will

- Provide requisite "cutting edge" program for maintaining technical superiority
- Favorably impact national economy through increased employment. Production and balance of trade
- Expand practical space applications for mankind's benefit

and

- Support national goals.

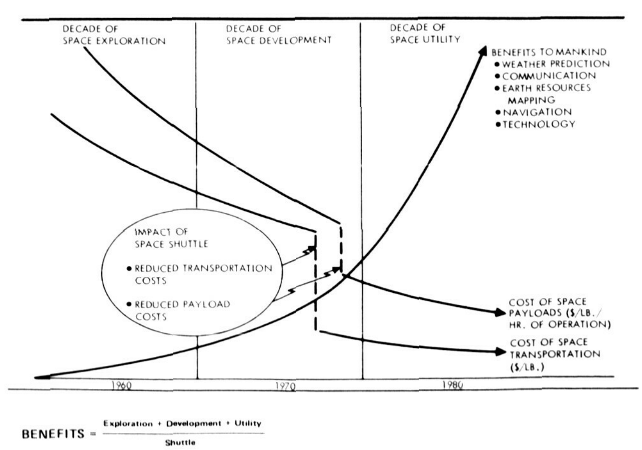


Figure 1. Benefits from the Space Shuttle.

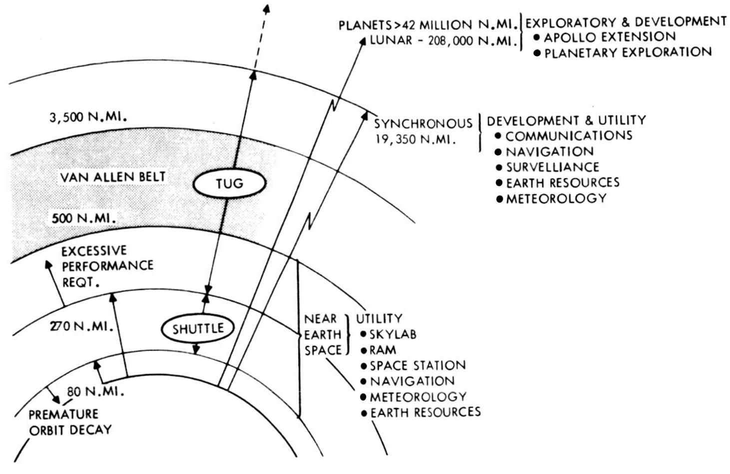


Figure 2. Space regions and operations for the Space Shuttle and Space Tug.

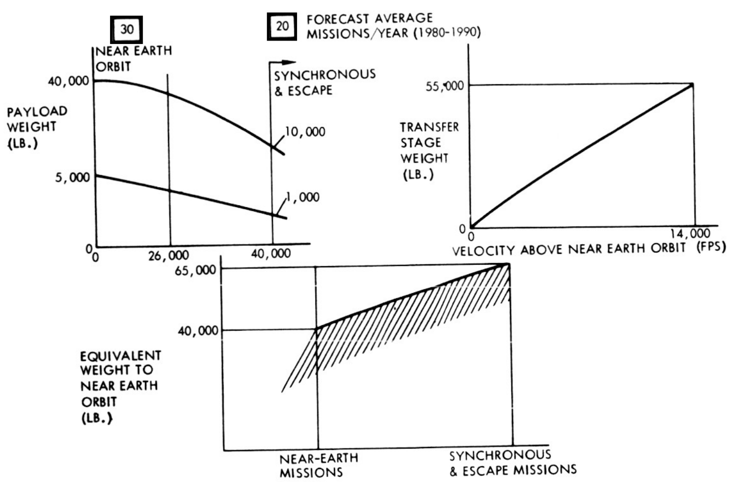
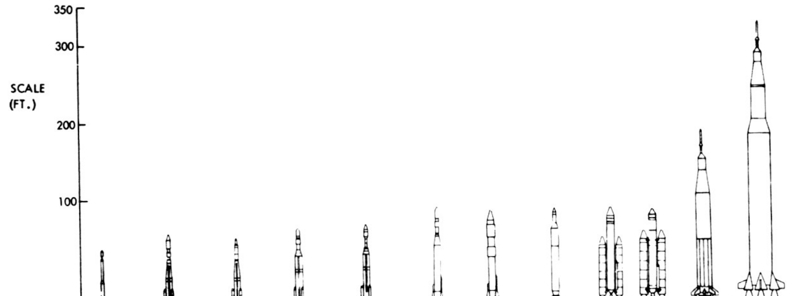


Figure 3. Weight of payloads at various orbits.



	SCOUT	TAT-DELTA (IMFROVED)	THOR AGENA D	LONG TANK TAT AGENA D	LONG TANK TAT IMP. DELTA	ATLAS/ AGENA D	ATLAS/ CENTAUR	TITAN IIIB AGENA B	TITAN IIIC	TITAN IIID	SATURN IB	SATURN V
PAYLOAD WEIGHT TO NEAR-EARTH ORBIT (LB.)	300	3,000	4,000	5,000	4,000	8,000	12,000	9,000	26,000	32,000	41,000	250,000
COST PER LAUNCH ($M)	3	6	8	8	6	9	11	9	15	11	50	200

Figure 4. Current U.S. inventory of space launch systems.

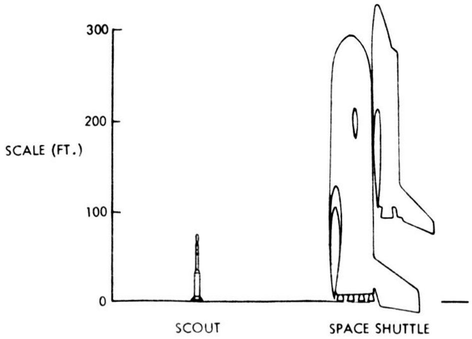


Figure 5. Comparison of the Scout and Space Shuttle.

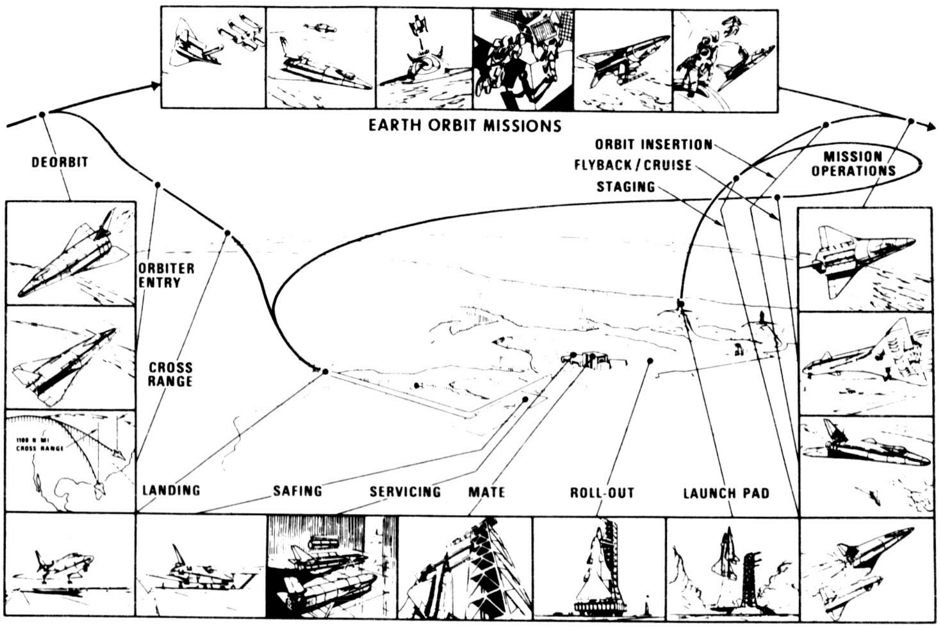


Figure 6. Mission profile.

Figure 7. Booster and orbiter in M&R facility.

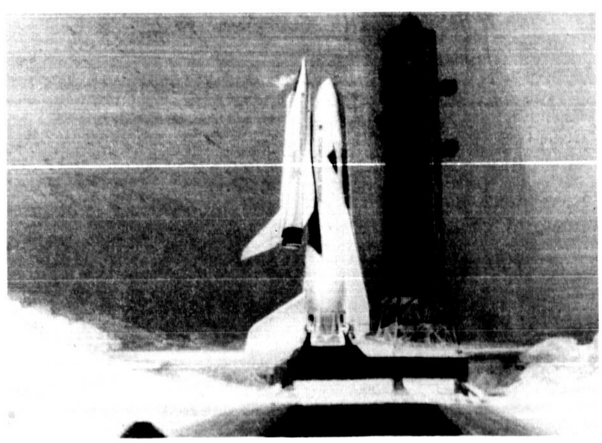


Figure 8. The Shuttle vehicle at liftoff.

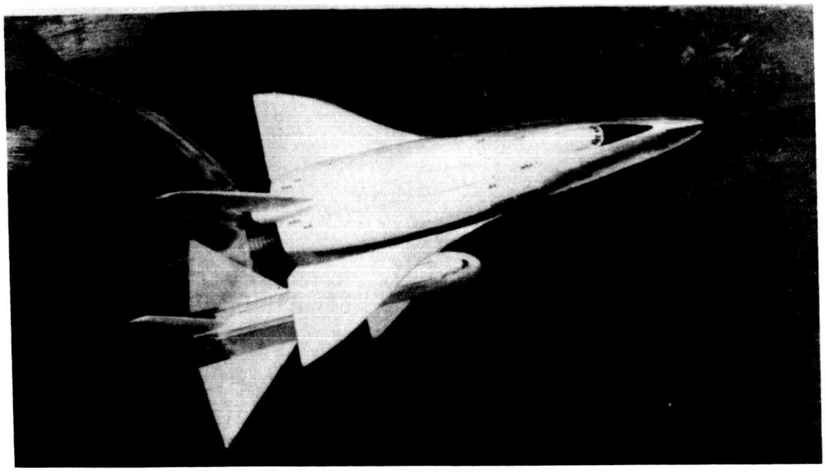
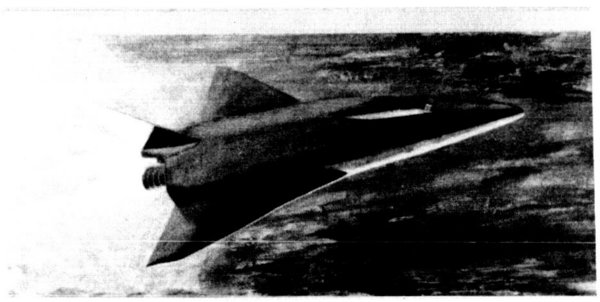


Figure 9. Booster and orbiter at separation stage.



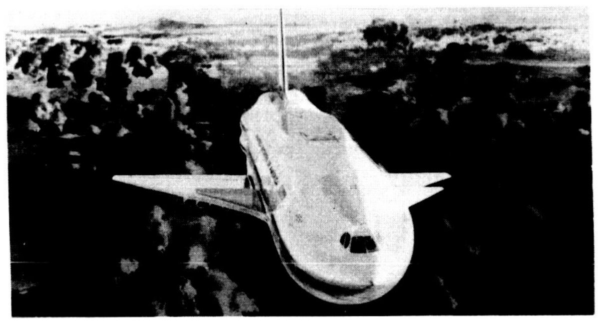


Figure 10. Completed separation of booster and orbiter.

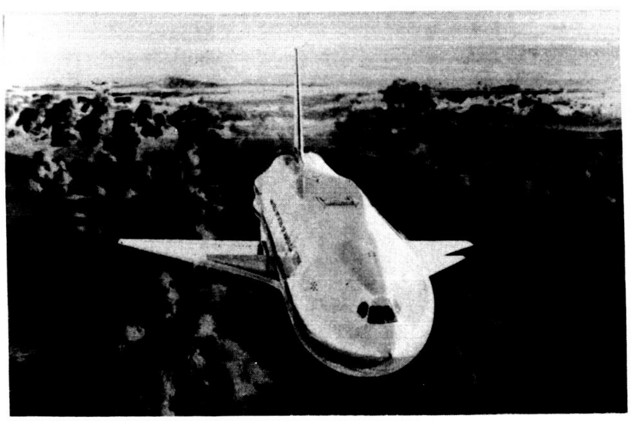


Figure 11. Booster during cruiseback to launch site.

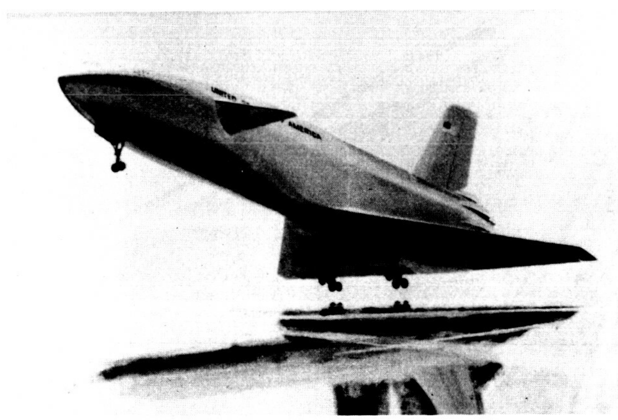


Figure 12. Booster at landing.

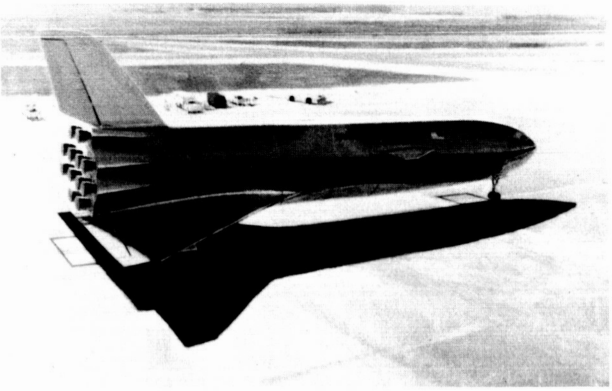


Figure 13. Booster in safing area.

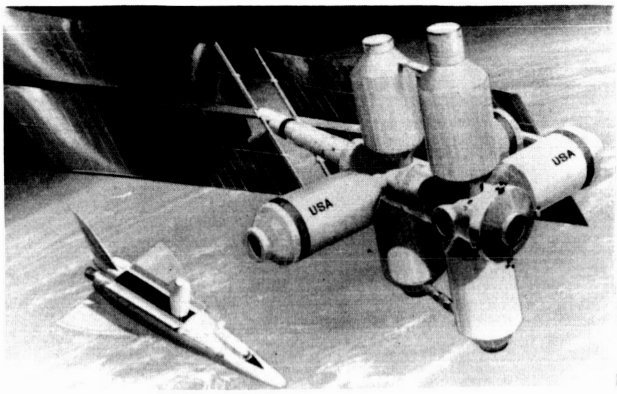


Figure 14. Orbiter unloading payload at Space Station.

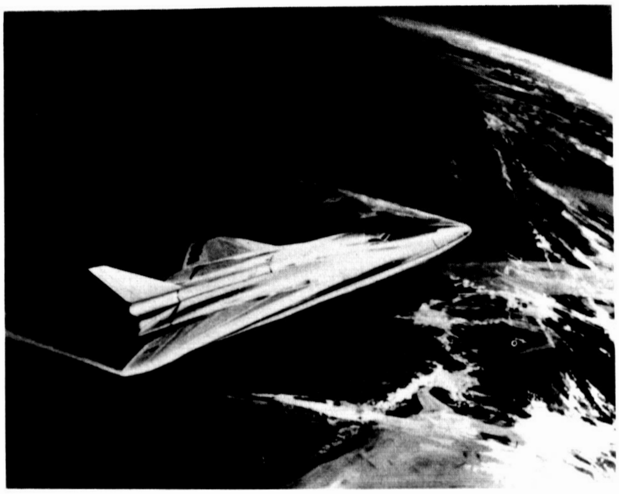


Figure 15. Orbiter during entry.

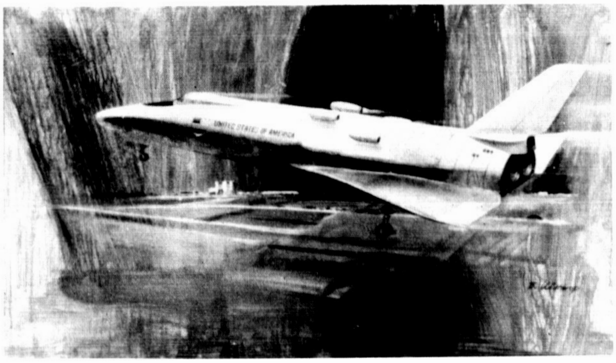


Figure 16. Orbiter at landing.

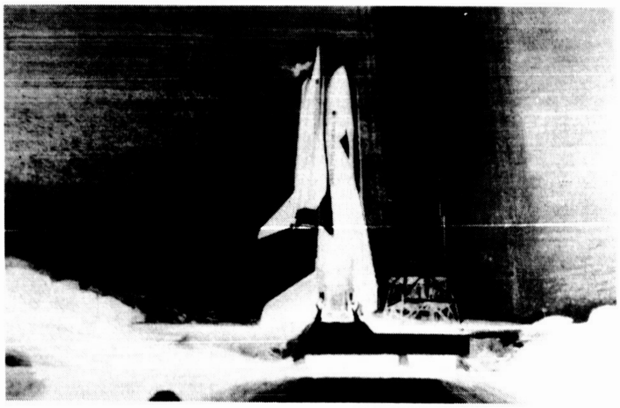


Figure 17. Two-stage launch vehicle.

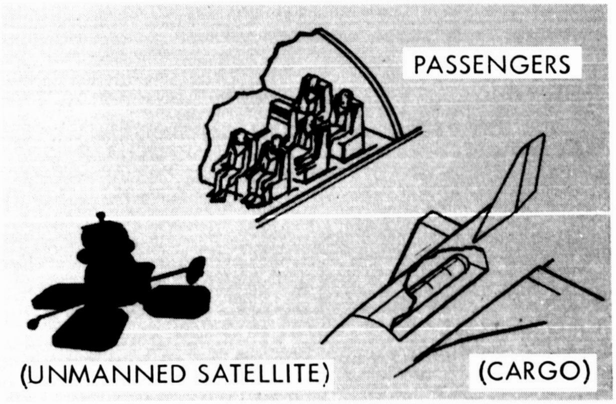
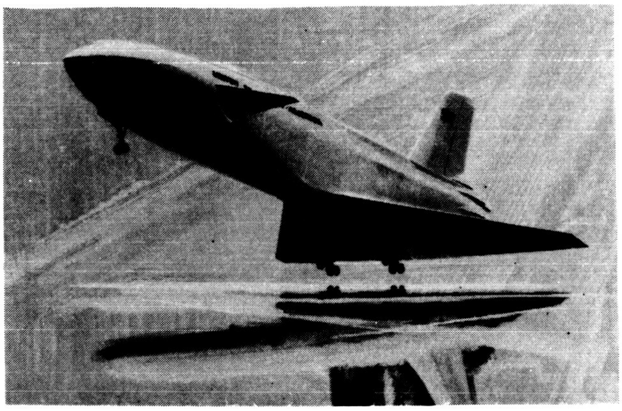


Figure 18. Transports to or retrieves from orbit.



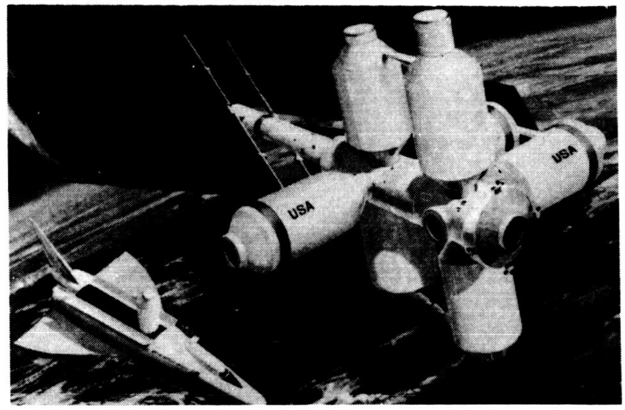


Figure 19. Services payloads and/or men on orbit.

Figure 20. Reusable.

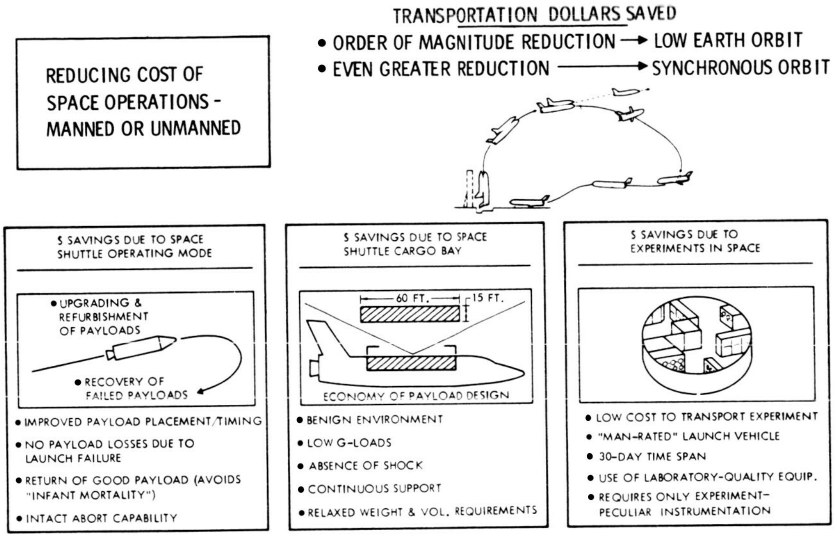
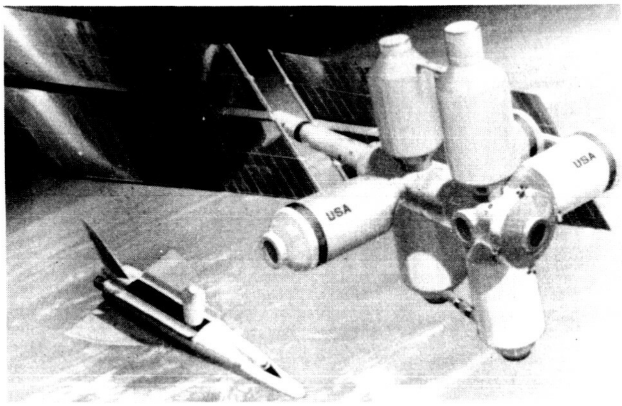


Figure 21. Cost reduction of space operations.



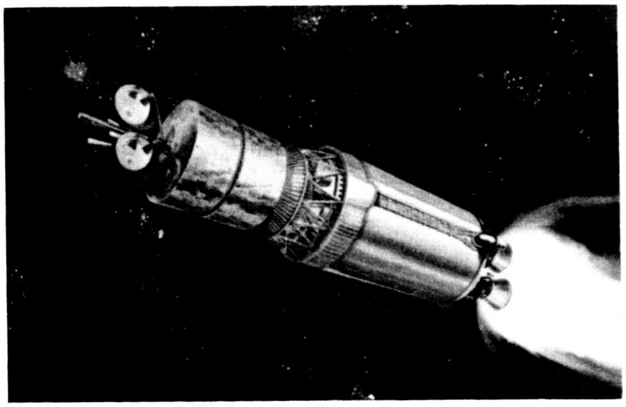


Figure 22. Space Station.

Figure 23. Space Tug.

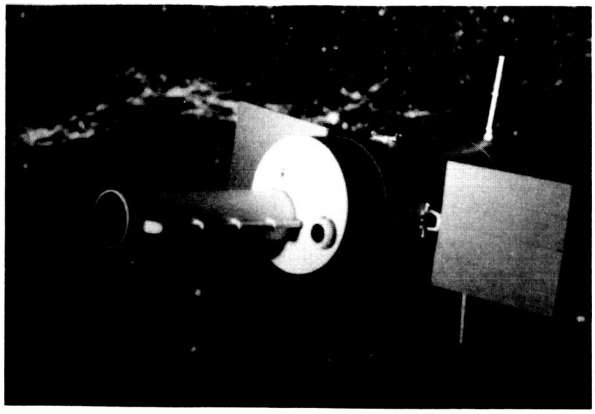


Figure 24. Research and Applications Modules (RAM).

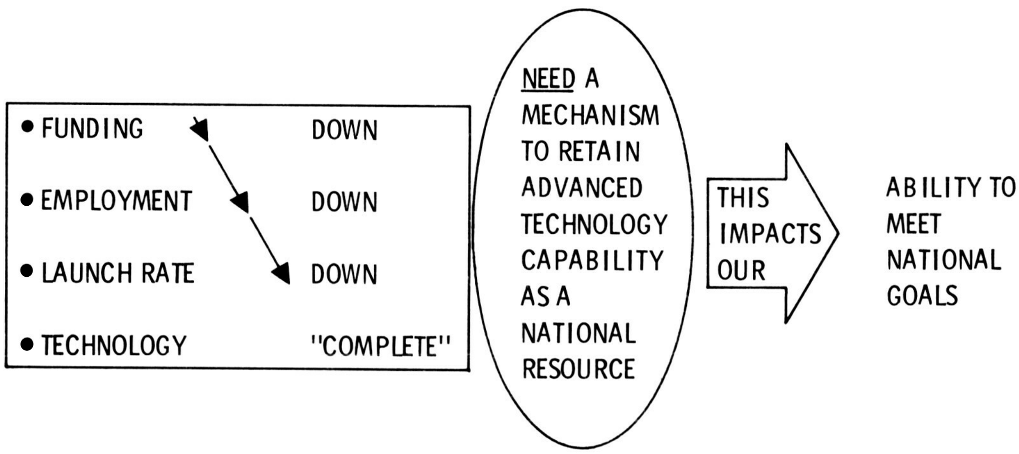


Figure 25. Impact upon technological superiority.

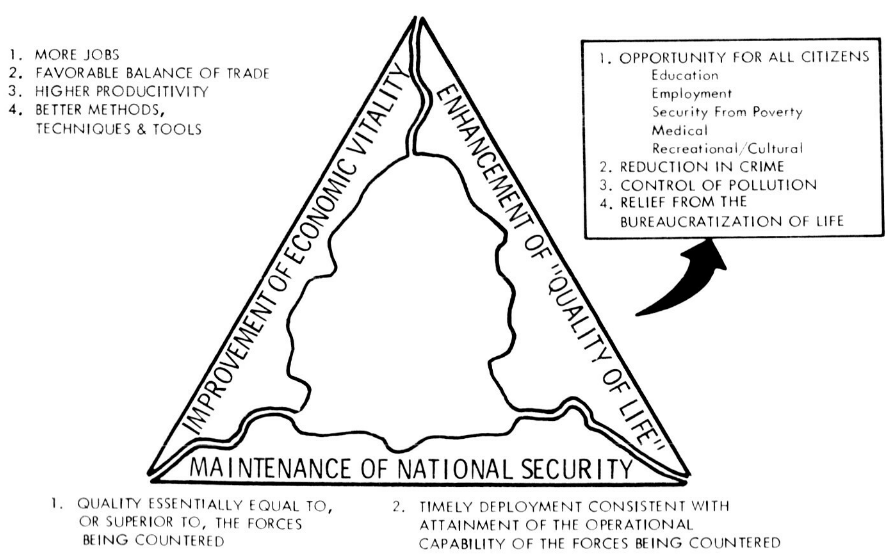
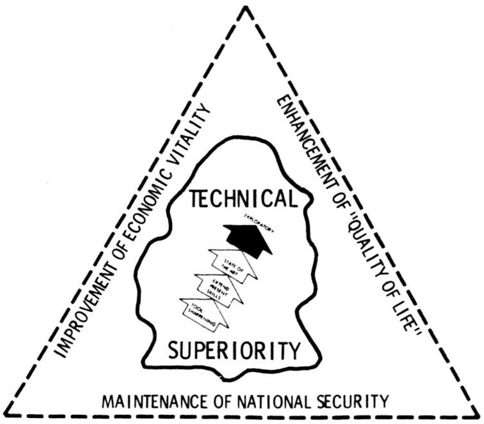


Figure 26. National goals.



- EXPLORATORY RESEARCH CONDUCTED IN INTEREST OF ADVANCING TECHNICAL SUPERIORITY
- DEVELOPMENT & "REDUCTION TO PRACTICE" OF STATE-OF-THE-ART TECHNOLOGY
- IMPROVEMENT & EXTENSION OF PRESENT TECHNICAL SKILLS
- SHARPENING & REFURBISHMENT OF APPLIED TECHNICAL TOOLS

Figure 27. Requirements and elements of technological superiority.

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(1) BASIC RESEARCH ACROSS A BROAD FRONT

(2) APPLIED RESEARCH IN SELECTED AREAS THAT APPEAR TO HAVE PROMISING POTENTIAL

- - - - - - - - - - - - - - - - - - - -

(3) "NEW BLOOD" IN THE FORM OF A CONTINUING SUPPLY OF YOUNG SCIENTIST AND ENGINEERS

(4) MULTIDISCIPLINARY MANAGEMENT/SCIENTIFIC/ENGINEERING/PRODUCTION TEAMS THAT INTEGRATE GOVERNMENT, UNIVERSITY,AND INDUSTRIAL ORGANIZATIONS AND MOTIVATE THEM TO ACHIEVE A COMMON GOAL

(5) MAJOR AND TECHNICALLY CHALLENGING DEVELOPMENT PROGRAMS OF NATIONAL SCOPE

Figure 28. Maintenance of technological superiority.

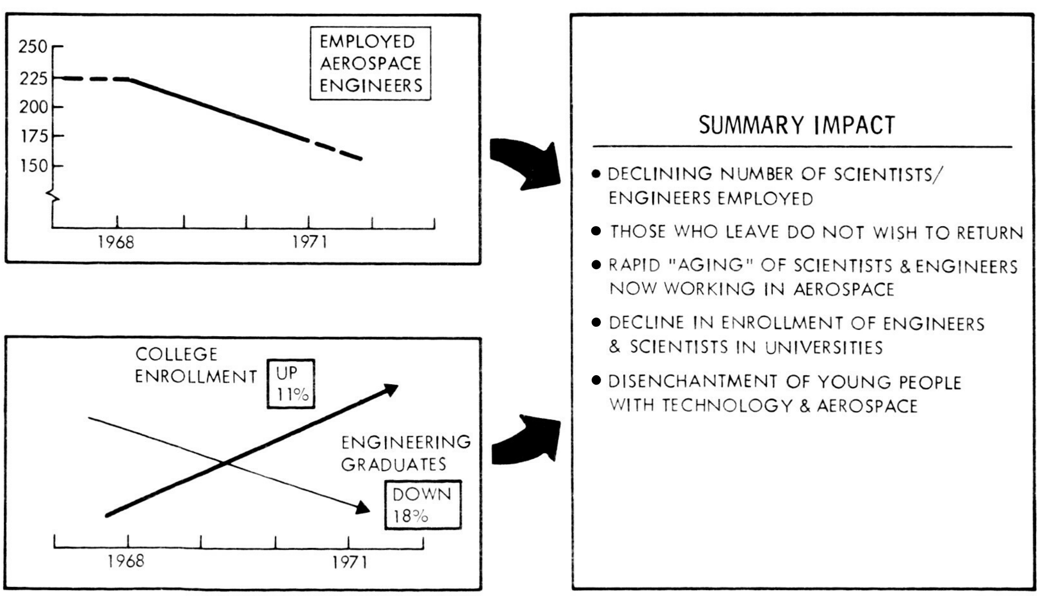


Figure 29. Current trends in availability of scientists and engineers.

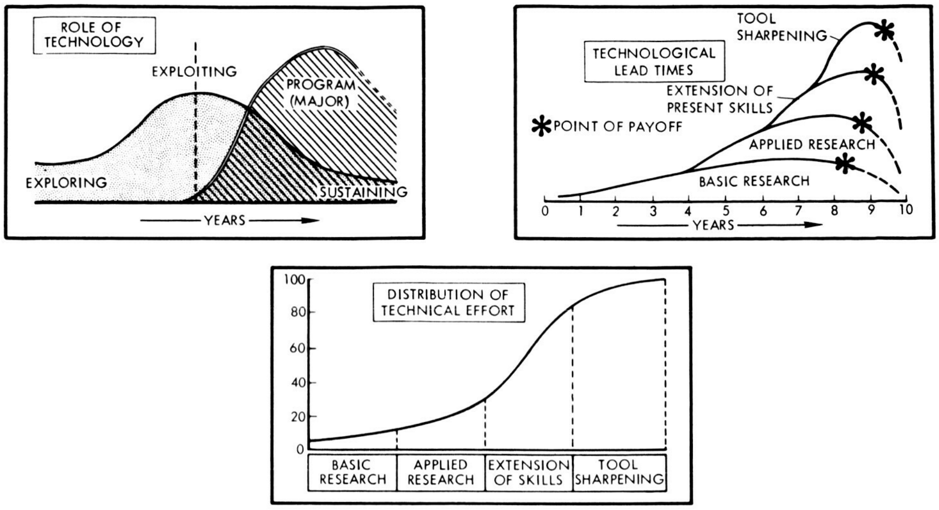


Figure 30. Three aspects of technology serving as the "cutting edge."

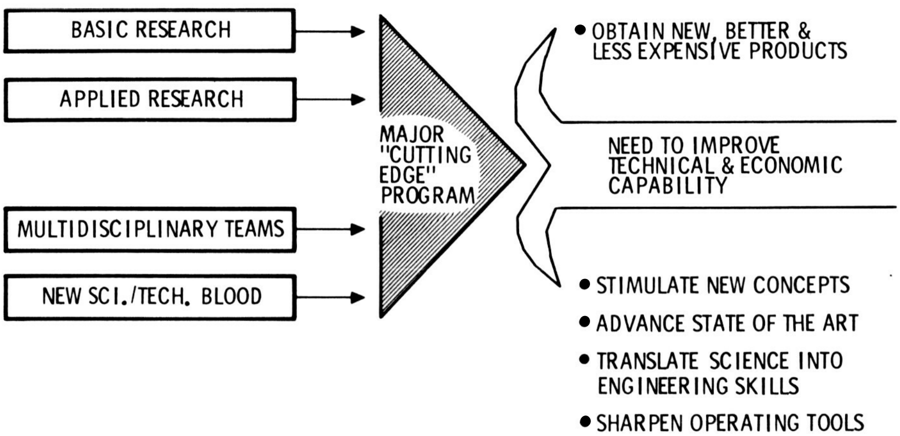


Figure 31. Integrating influence of "Cutting Edge" programs.

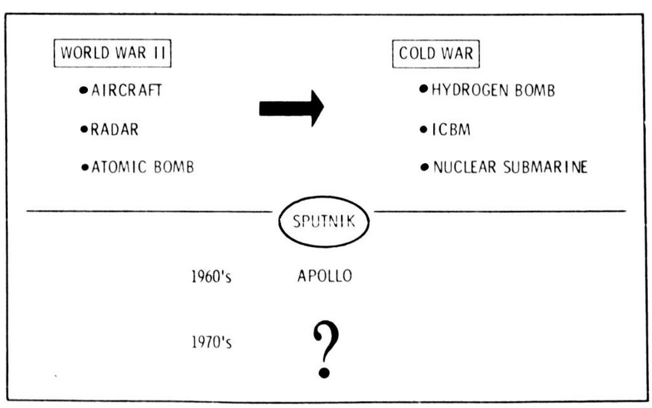


Figure 32. Major "Cutting Edge" programs.

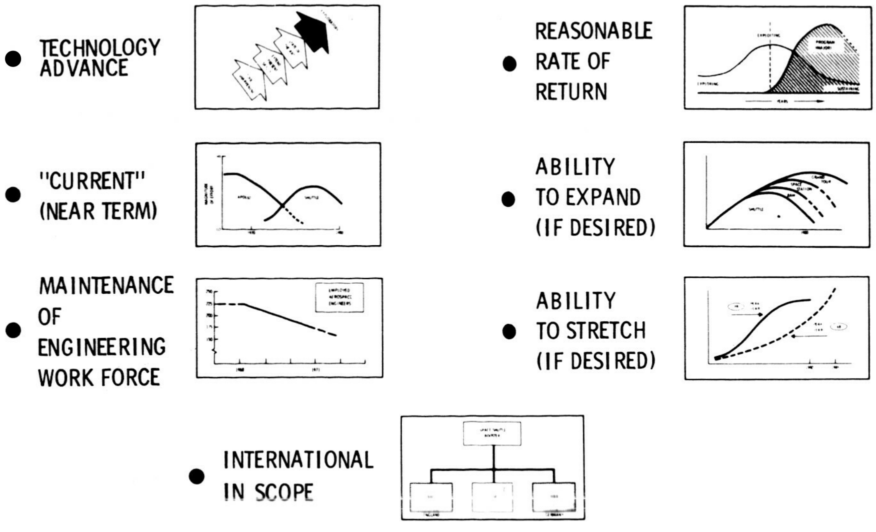
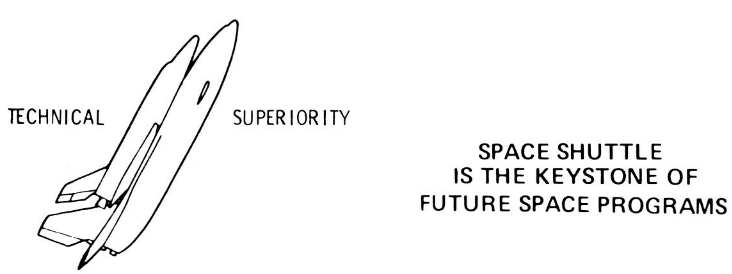


Figure 33. Required programs features.

- A MAJOR NEW PROGRAM MUST
  - ∕ PRODUCE AN END PRODUCT THAT YIELDS DIRECT BENEFITS TO NATION
  - ∕ PROVIDE A TECHNOLOGICAL INTEGRATING INFLUENCE
  - ∕ SLOW DOWNWARD TREND IN NUMBERS OF EMPLOYED ENGINEERS & SCIENTISTS
  - ∕ ATTRACT & RETURN YOUNG ENGINEERS & SCIENTISTS
  - ∕ SLOW OR REVERSE THE RAPID "AGING" OF AEROSPACE TECHNICAL TEAMS
  - ∕ SLOW SHARP DOWN-TREND IN ENROLLMENT IN SCIENCE & ENGINEERING SCHOOLS
  - ∕ MAINTAIN MULTIDISCIPLINARY GOVERNMENT & INDUSTRY TEAMS

Figure 34. Required results of new "Cutting Edge" program.



- REDUCING THE COST OF SPACE OPERATIONS – MANNED OR UNMANNED
- SPACE SHUTTLE: BASIC TO FUTURE SPACE DEVELOPMENT ACTIVITIES

Figure 35. Space Shuttle as keystone to future space operations.

- WILL STIMULATE ABOUT 20 BILLION OF DOMESTIC PRODUCTION
- WILL PROVIDE OVER 400,000 MANYEARS OF EMPLOYMENT IN AEROSPACE INDUSTRY
- WILL ALSO PROVIDE MORE THAN 280,000 MANYEARS OF NONAEROSPACE EMPLOYMENT REQUIRED TO SUPPORT PROGRAM
- WILL HELP U.S. BALANCE OF TRADE BY STIMULATING OUR HIGH TECHNOLOGY EXPORT INDUSTRIES
- WILL REQUIRE FEWER IMPORTS THAN WOULD A RESIDENTIAL HOUSING CONSTRUCTION PROGRAM OR AN INCREASE IN CONSUMER SPENDING OF COMPARABLE SIZE

Figure 36. Comparative impact of three environment programs.

	CONSUMER SPENDING	SPACE SHUTTLE	RESIDENTIAL CONSTRUCTION
TOTAL PRODUCTION*	$19,100	$20.000	$ 16,500
PER CENT AEROSPACE	0%	62%	0%
MAJOR INDUSTRIES AFFECTED	• RETAIL TRADE • REAL ESTATE • WHOLESALE TRADE	• AIRCRAFT • MISSILES & SPACE • COMMUNICATIONS	• CONSTRUCTION • LUMBER • CEMENT/GYPSUM
BALANCE OF TRADE			
REQUIRED IMPORTS*	✓ $435	$300	$430
INDUCED EXPORTS	✓ LOW	HIGH	LOW

*1970 DOLLARS IN MILLIONS

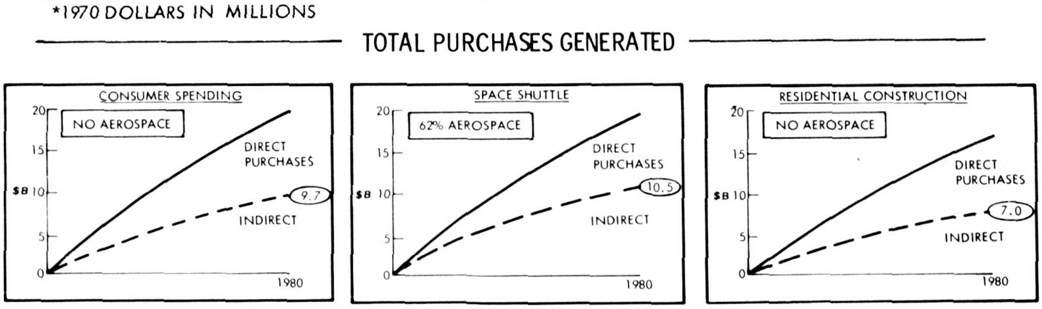


Figure 37. National economic benefits of the Space Shuttle programs.