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SPACECRAFT 2000 - THE CHALLENGE OF THE FUTURE

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Considerable opportunity exists to substantially improve the systems, subsystems, components, etc., included in the spacecraft bus, the nonpayload portion of the spacecraft. There are a broad range of technology advancements which can be brought to bear to reduce mass and cost and to increase lifetime and reliability. Over the past several years, the NASA Lewis Research Center has been working with industry, other NASA centers, and the Department of Defense (DOD) to define a new initiative that would focus on these issues, while at the same time forging new industry/government relationships that can lead to substantial benefits for both parties. The steps followed to date, the challenges being faced by industry, and the progress toward establishing a new NASA initiative which will identify the technologies required to build spacecraft of the 21st century and which will implement the technology development/validation programs necessary are described in this paper.

INTRODUCTION

Historically, the primary focus of a spacecraft designer's attention has been the payload, and this seems most reasonable. After all, the payload is the primary purpose for the existence of a satellite. However, this mode of thinking inevitably leads us into a delicate trap. The emphasis placed on increasing the sophistication of the payload (often at substantial risk) in order to accomplish the desired mission, tends to decrease the attention paid to making substantial improvements in the spacecraft bus. Figure 1 demonstrates that the payload comprises only one-fourth of the total geosynchronous (GEO) spacecraft mass and the ratios are similar for low-Earth orbiting (LEO) spacecraft. Unfortunately, spacecraft managers are less concerned with the potential benefits than the risk of making substantial changes in the bus portion of the spacecraft. It is only when the mass of the spacecraft approaches launch vehicle capacity that investment in new spacecraft bus technology becomes compelling. One example of this is the development by COMSAT Laboratories and the U.S. Air Force (USAF) of the individual pressure vessel nickel-hydrogen battery for geosynchronous applications.

In addition to being three-fourths of the spacecraft mass, the bus (defined as power, thermal management, auxiliary propulsion structure, attitude control, and telementry, tracking, and control (TT & C) incurs about one-half the satellite's cost (pretest and checkout). Cost is, of course, the major challenge to be met. In the commercial world, reduced cost means enhanced revenue or increased competitiveness. Figure 2 shows data demonstrating the sixfold reduction in INTELSAT utilization charges over the past two decades. In the competitive communications business, cost reduction is essential to profitability.

Cost reduction plays an important role in other classes of satellites - from commercial ventures in low-Earth orbit to satellites whose sole goal is scientific knowledge. For these, cost reduction is often essential to a profitable product or the ability to fly the mission. Other major factors, such as increased performance, which enter into the arena as well will be addressed later.

In late 1984, it became apparent that a new kind of government-supported program, one that focuses on the spacecraft bus and enhanced industry-government partnership, might be in the nation's best interests. Over the past two years, we at NASA Lewis Research Center have been pursuing a path which we hope will lead to a major new initiative for NASA. It is appropriate now to review the steps that have been taken and the progress that has been made toward this goal.

PROGRAM DEVELOPMENT

The decision to pursue developing this new initiative resulted from a series of visits that the Lewis staff paid to industry in the spring of 1985. The objective was to obtain industry's view of the critical problems it was facing in its satellite business ventures. Nine organizations were visited as shown in figure 3. The range of business orientation spanned government (NASA and military), commercial communications, and communications operations. Critical concerns were identified. These included reducing spacecraft related costs and subsystem weights, increasing system lifetimes and reliability, and reducing technical risks. It is important to note that each company saw specific future technical needs somewhat differently. However, there was consensus that there was a real need to address the development of the spacecraft bus technologies.

The initial program focus was aimed at the broad range of satellites that fall generally into the classification of mass-limited missions. These include GEO satellite's and platforms, LEO polar satellites and platforms, and planetary spacecraft. This distinction, while somewhat arbitrary, is certainly helpful programmatically. It is also obvious that advances made in one class of satellites will be transferable to others.

It should be noted that mass-limited missions really reflect Earth-to-orbit booster limitations. This is most clearly shown in figure 4 which demonstrates the situation in power. For this figure, the power was computed from the known mass-to-GEO capability of the booster stage (IUS or STS/centaur), the 25 percent mass due to the power system, and the specific mass of the power system. Current technology benchmark was taken as the TDRS power system which was 7.2 W/kg for solar array, battery, cabling, and power management. With present technology a stringent limit is placed on the power available in orbit. Advanced technologies can substantially eliminate such restrictions. It is important to note that a 40 W/kg power system could be built from technologies currently under development by NASA OAST (figure 5). Similar advances are possible in all other areas of the spacecraft bus. It is entirely possible to double the payload mass fraction by focusing attention on improvements in the bus and in the design of spacecraft. This additional mass can be used to enhance reliability, add lifetime, or increase revenue.

Finally, it was also clear from these visits that international competition was becoming intense and aggressive. A cursory examination of foreign developments in power and electric propulsion showed significant activity that was promising enhanced capability. For example, figure 6 denotes the activity in European solar array development overlaying a projection by Pierce (RCA) of satellite power needs up to the next century. The European solar array developments are all available today (they are arbitrarily distributed over time to show detail). Similar U.S. array developments have been minimal. Figure 7 demonstrates the increased voltage of European satellites in contrast to the 28 Vdc U.S. standard. Increases in voltage permit substantial reductions in cabling mass. Figure 8 shows the flights of electric propulsion systems by foreign sources, while U.S. technology has been dormant for nearly two decades.

With these examples, it is clear that there is great potential for substantial improvements in all areas of the spacecraft bus. Industry and government agree. The question is "how to proceed?"

PROGRAM APPROACH

The first step was to establish a steering committee comprised of industry, several NASA centers, and critical DOD organizations. This group reached agreement on several key points. First, they emphasized that a government/industry partnership was desirable and in the nation's best interest. The hope is that a government/industry relationship can be developed in the space arena which parallels the one that exists in the aeronautical arena. In this partnership the government supports high-risk research; industry takes the results and turns them into commercial advances. The challenge is to expand the technology-availability time horizon of industry and to bring government-sponsored research more near term.

Secondly, a total system approach at the spacecraft level should be used to define technologies for development. The technology developments should be focused and a combination of existing, modified, or new NASA and industry IRAD programs. The challenge will be to maintain proprietary rights within the company and to establish a program wherein participating organizations would develop those technologies that they view to be in their best interest. The program is not envisioned to be the traditional program in which a system is defined (e.g., a 40 W/kg power system), and a competition ensures with an organization ultimately being selected to perform the work. It is clear that many challenges must be overcome to make this approach a reality.

Next, many supporting technology issues may also have to be addressed - manufacturability, testing, servicing, supportability, etc. It will be essential to understand the operating environment of the 21st century and how it will influence satellite design. Equally important is the use of autonomy (in orbit, support, etc.) in satellite development and operation to permit a better product at a reduced cost.

Finally, the industry/government steering committee indicated the need for validating technology using terrestrial and/or in-space testbeds. This would include space act agreements covering the use of government-owned testbeds and judicious in-space testing as absolutely necessary.

The steering committee support for this new initiative has been outstanding and enthusiastic. All participants have shown a keen desire to create a new mode of operation that will enable the prompt introduction of new technologies and new ways of building and operating future spacecraft.

THE WORKSHOP

As part of developing the Spacecraft 2000 initiative, a workshop was held July 29-31, 1986 in Cleveland, Ohio. The objectives of the workshop were to identify the critical needs and technologies for spacecraft of the 21st century and to recommend technology development/validation programs and possible government/industry roles and partnerships. Forty-two organizations from both government and industry participated in the workshop. As a common base, plenary sessions delineating spacecraft needs and trends and outling the expected space infrastructure for the year 2000 were presented. Nine working group sessions covering all critical spacecraft bus technologies and systems were conducted. Each group was cochaired by industry and government representatives. In each of these working group sessions, critical technologies were identified. It was evident from the output of the groups that a bridge is required for new technologies to reach flight readiness. The need for government-sponsored terrestrial and/or in-space test beds for technology validation was also emphasized in each of the reports. During the course of the workshop, the steering committee also deliberated on government/industry relations to find common ground and a satisfactory approach for the program. Enthusiastic industry and government support for the Spacecraft 2000 program was evident. This workshop represents the first step in establishing the foundation for a new initiative to assure the broadband advocacy by all participants and to define a new partnership between government and industry that will lead to future enhancement of the spacecraft industry.

CONCLUSIONS

It is clear that the potential exists for major gains to be made in spacecraft of the 21st century. Specifically, the mass fraction of the payload could be doubled through substantial reductions in the bus mass fraction. This can be accomplished along with significant reductions in cost and increases in lifetime and reliability. Additional advances are anticipated in manufacturability, testing, servicing, and supportability. These benefits apply to all spacecraft (NASA, DOD, and commercial) and to areas such as communications, Earth observation, navigation, rescue, air traffic control, etc. The resulting cost reductions and performance improvements of this program will enable new cost-effective missions and allow enhanced competitiveness in world markets and with terrestrial alternatives.

A NASA/DOD/industry steering committee is intent on forging a new government/-industry relationship that results in benefit to both and minimizes the liabilities. The hope is to create in the space business a government/industry relationship similar to that found in the aeronautical business. The challenge (and the vision) is to construct a program that allows individual organizations to develop and validate critical technologies by judiciously using government, IRAD, and some corporate funds and to maintain their proprietary rights thus enhancing both their intraand international competitiveness. All parties can win, and the world can benefit from the successful conduct of this program.

Support for this new NASA initiative, Spacecraft 2000, is growing in industry and in government. The next year will be important, as the 1986 workshop will provide the technological foundation and the basis for government/industry relationships. The multifaceted advocacy can then be undertaken that could result in a new initiative as early as 1989.

We believe the Spacecraft 2000 initiative addresses the major needs and technological drivers for the spacecraft of the 21st century. We all must work together to bring this vision of the future into being for the national best interest.

SPACECRAFT BUS TECHNOLOGY

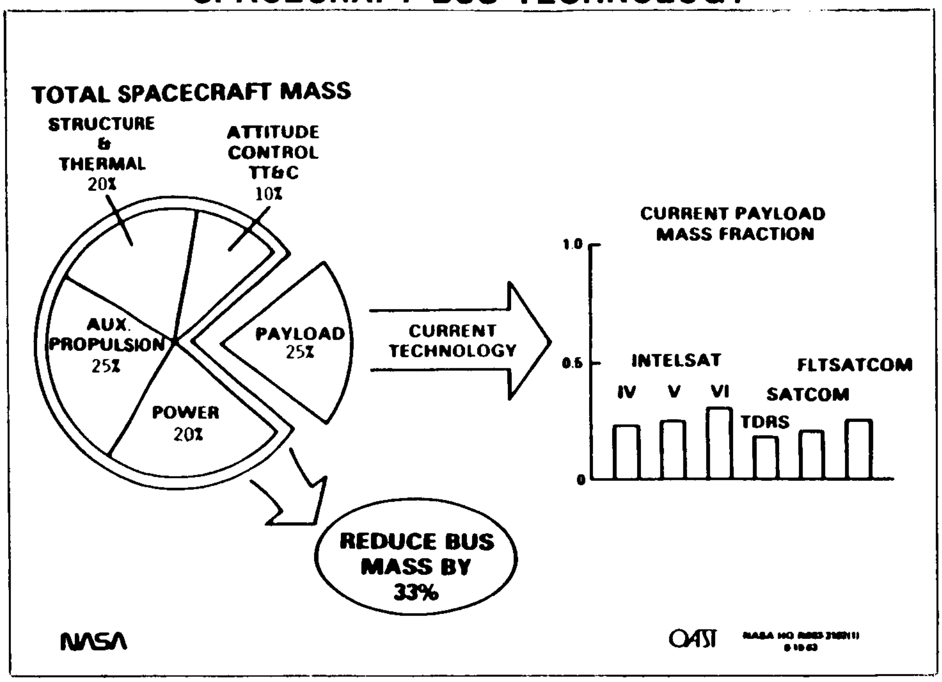

Figure 1.

INTELSAT SATELLITE UTILIZATION CHARGE

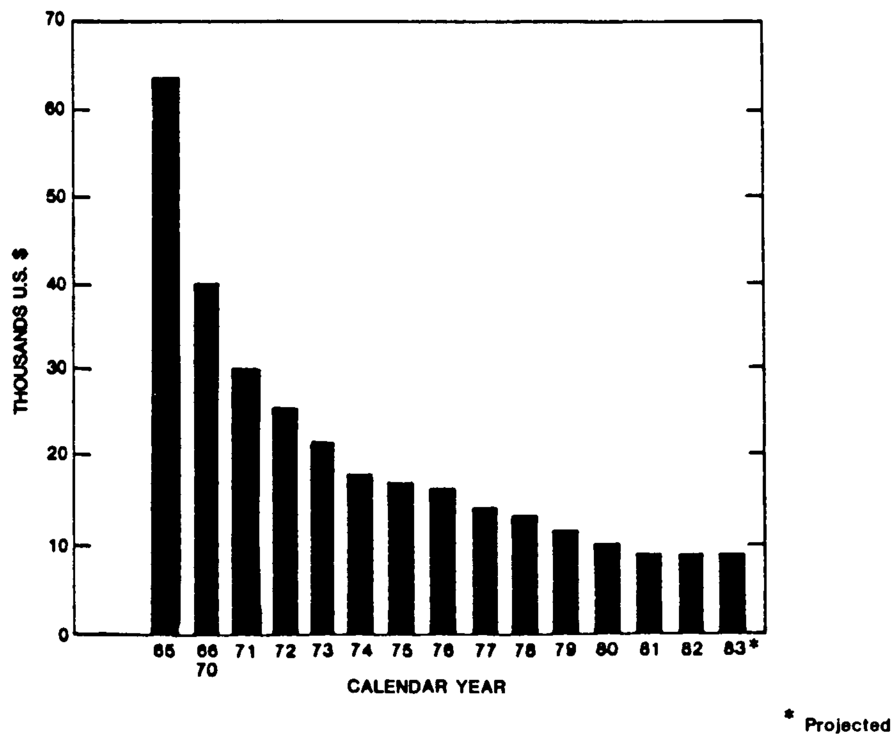

Figure 2.

SPACECRAFT 2000 INDUSTRY VISITATIONS

GENERAL ELECTRIC

FAIRCHILD CORPORATION

FORD AEROSPACE CORPORATION

LOCKHEED MISSILES AND SPACE CORPORATION

TRW INCORPORATED

ROCKWELL INCORPORATED

HUGHES AEROSPACE CORPORATION

RCA ASTRO DIVISION

COMSAT CORPORATION

Figure 3.

ADVANCED TECHNOLOGY FOR GEO POWER SYSTEMS

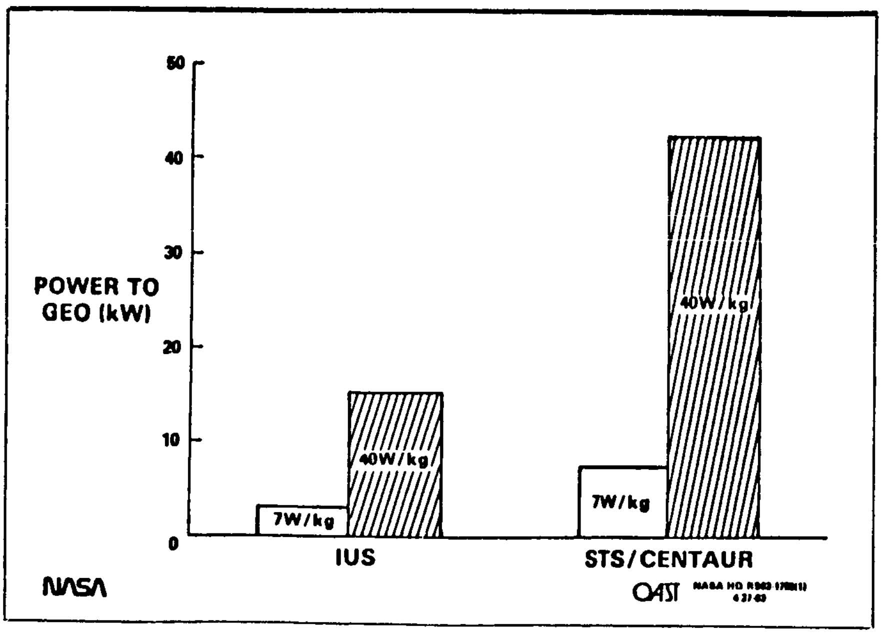

Figure 4.

ADVANCED GEO POWER SYSTEM TECHNOLOGY

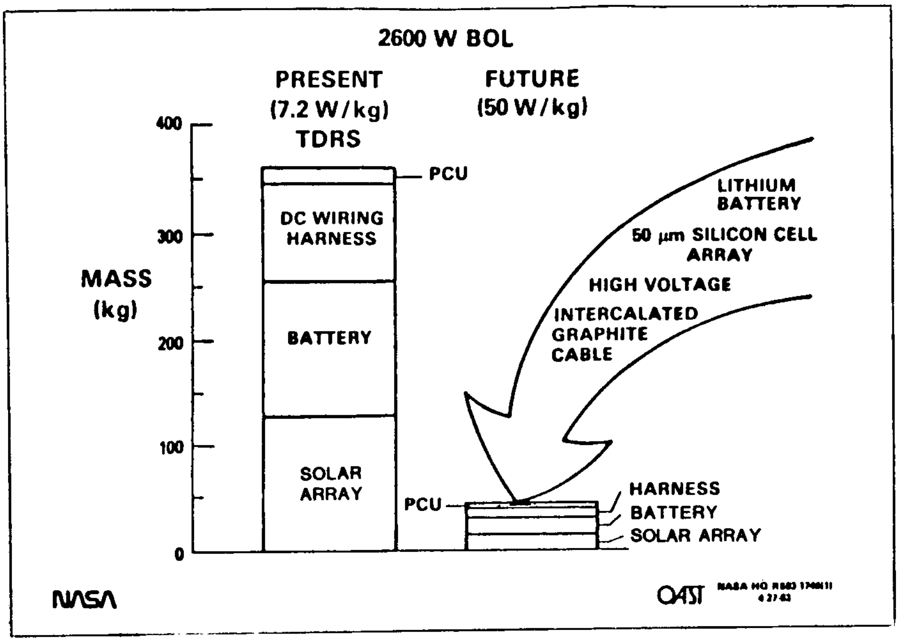

Figure 5.

EUROPEAN SOLAR ARRAY TECHNOLOGY

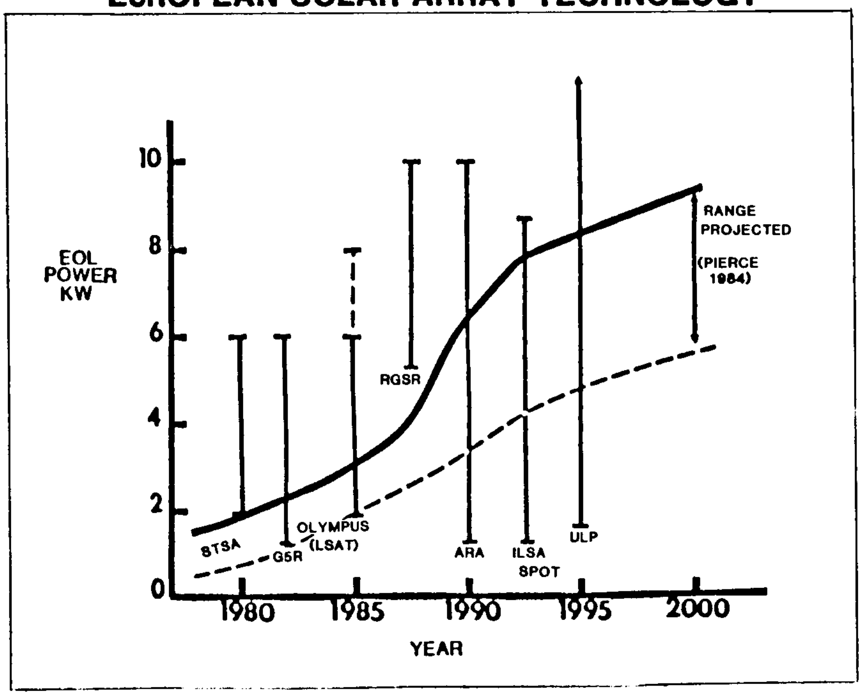

Figure 6.

SPACECRAFT BUS VOLTAGE

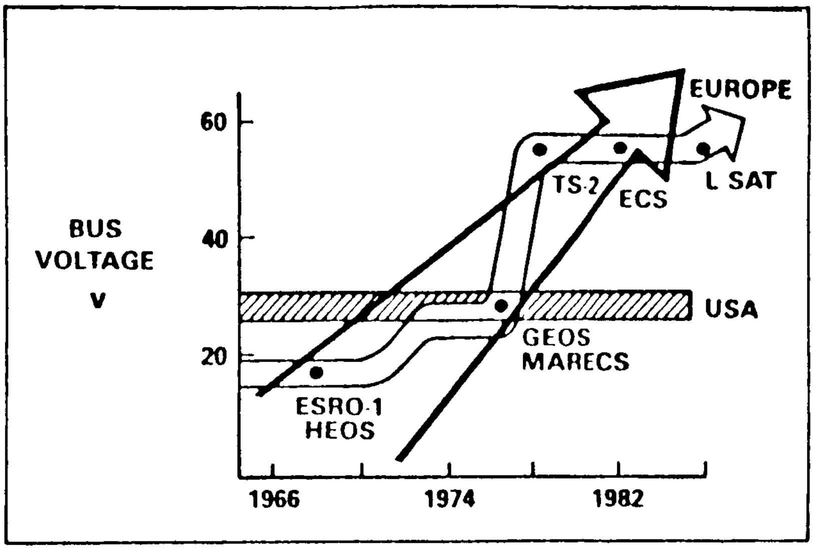

Figure 7.

ELECTRIC PROPULSION PROGRAMS

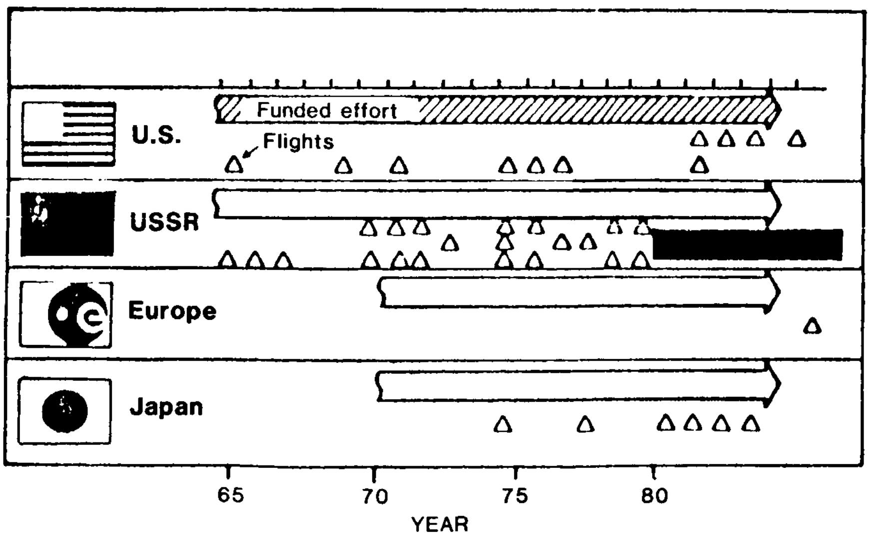

Figure 8.