EXPLORATION COMMITTEE

SUMMARY REPORT TO THE NAC – 19 JULY 2007

FOR THE COMMITTEE

LtGen James Abrahamson

Exploration Committee

ONGOING REVIEWS

Requirements documents and flow to specifications and procurement issues: Continuing including Stretch Requirements and Small Business initiatives.

New Reviews and Recommendations for July

- **Threats to NASA Computers and Operations.**
- **Balancing advancing technology.**

Requirements Review

- **Hqts review of requirements documents.**
- **Excellent correlation between requirements and early RFP development.**
- **Good correlation and completeness IAW solid Work Breakdown structures.**
- **Raised minimal process questions:**
  - **i.e. implementation of "Stretch Requirements"**
  - **and role of small business for innovation.**

FACT FINDING DURING JULY 2007 NAC MEETINGS

- **Transition Infrastructure—joint with Space Operations and Audit and Finance Comm.**
- **NASA/NIH MOU Status and Results from Workshop on Biomed Implications of Lunar Outpost Architecture—with Space Ops Comm.**
- **Constellation Ground, Flight Test Operations Planning with Space Ops Committee.**
- **Stretch Requirements Summary**
- **MSFC Small Business Office Discussion**
  - **Aires Advanced Technologies**

FACT FINDING DURING JULY NAC MEETING (continued)

- **Constellation Capability for Asteroid Destinations: with Space Operations Committee.**
- **Lunar Architecture Team Status: with Space Operations Committee.**
- **MSFC Project and Facilities Tour: with entire NASA Advisory Council.**

RECOMMENDATION #1

Threats to NASA Computers and Operations.

By

Dr. Ken Ford

RECOMMENDATION # 2

Balancing Advancing Technology

The Exploration Committee

Don Fraser

Rick Hauck

Ken Ford

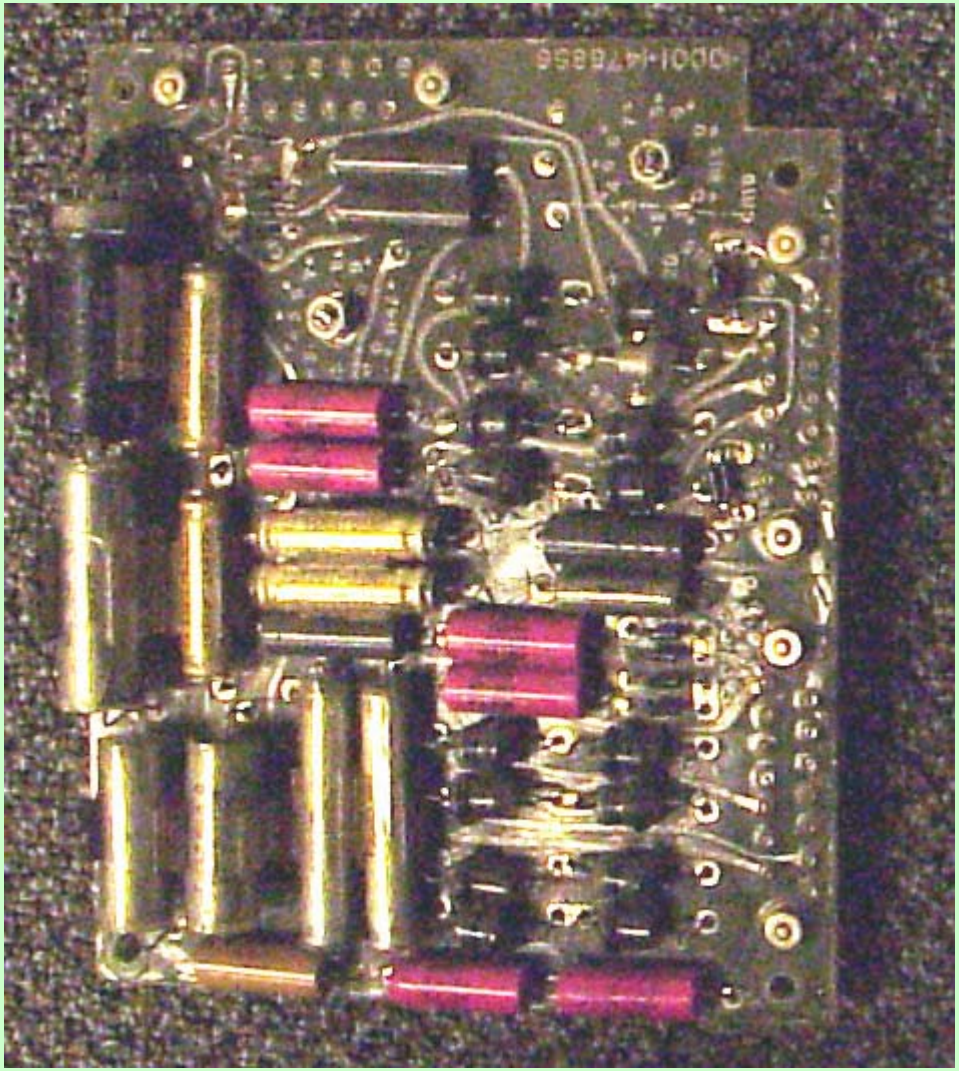
Jim Abrahamson

John Logsdon

A GENERIC HIGH TECHNOLOGY ISSUE

- **Choosing the proper level of technology maturity to incorporate into the design!**
- **Selecting a technology that is too far back starts the design "on the edge of obsolescence".**
  - **Lots of experience provides confidence in the process**
  - **Initial costs may be low, but life cycle costs may not be apparent--i.e. old parts and old processes will soon be out of production and require development for spares.**
  - **Design tools and incorporated software may be out of date and not remain vital for future upgrades.**
- **But starting too advanced carries immaturity risks at all levels of development and high costs.**

Was (Early 60s)Apollo



Component Types:

Through-hole analog

Assembly Methods

Hand assembly with hand soldering

Design Methods

Manual layout

Average Density

1.13 components per square inch

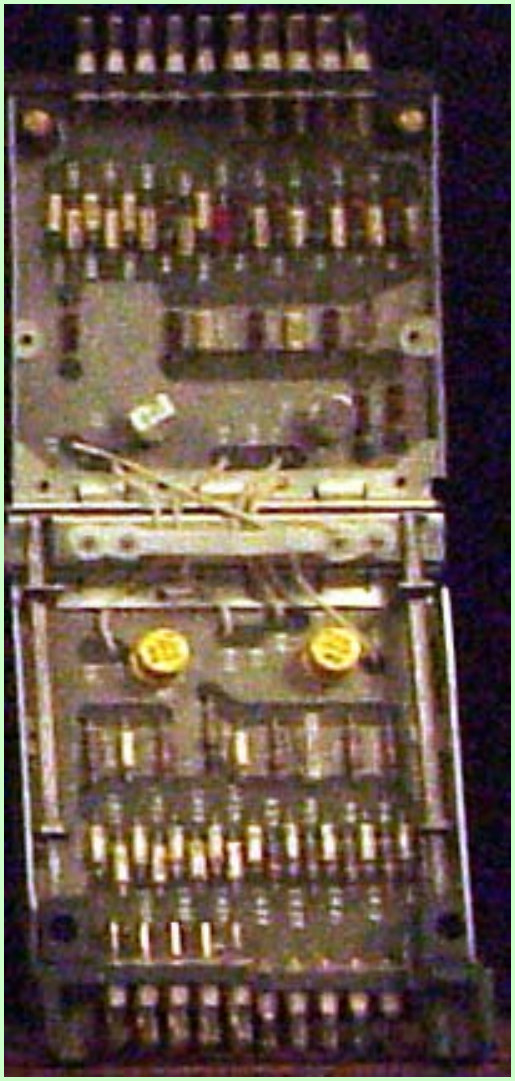
PCB Fabrication

Double sided through-hole with the use of eyelets and minimum line spacing of .050”

Board Description

The power supply board was designed for use in harsh environments. Note the mechanical components and conformal coating

Was (Late 60s)



Component Types:

Through-hole analog and

transistor components

Assembly Methods

Hand/machine assembly with wave soldering

Design Methods

Manual layout

Average Density

3.1 components per square inch

PCB Fabrication

Double-sided through-hole with the use of eyelets and minimum line spacing of .030”

Board Description

An ordnance controller designed for extreme environments. Note the modular design for quick removal and replacement.

In work

Initial IC development with hundreds of transistors on a single semiconductor chip

Was (Early 70s)Shuttle

Component Types:

Through-hole analog and digital components

Assembly Methods

Hand / machine assembly and wave soldering

Design Methods

Early CAD layout

Average Density

7.6 components per square inch

PCB Fabrication

Double sided through-hole with the use of eyelets and minimum line spacing of .030”

Board Description

An early example of commercial microprocessor technology in a high density through hole design. This type of packaging was made possible by the use of computer added design tools. Note the use of solder mask to improve wave soldering yields as the component density increases.

In work:

Small Scale Integration (SSI)

Medium Scale Integration

(10-1,000 transistors per IC with 14-24 I/Os)

Functional Network

Was (Late 70s) Hubble

Component Types:

Through-hole analog and digital components

Assembly Methods

Machine assembly and wave soldering

Design Methods

CAD layout

Average Density

11.5 components per square inch

PCB Fabrication

Double sided through-hole with the minimum line spacing of .020”

Board Description

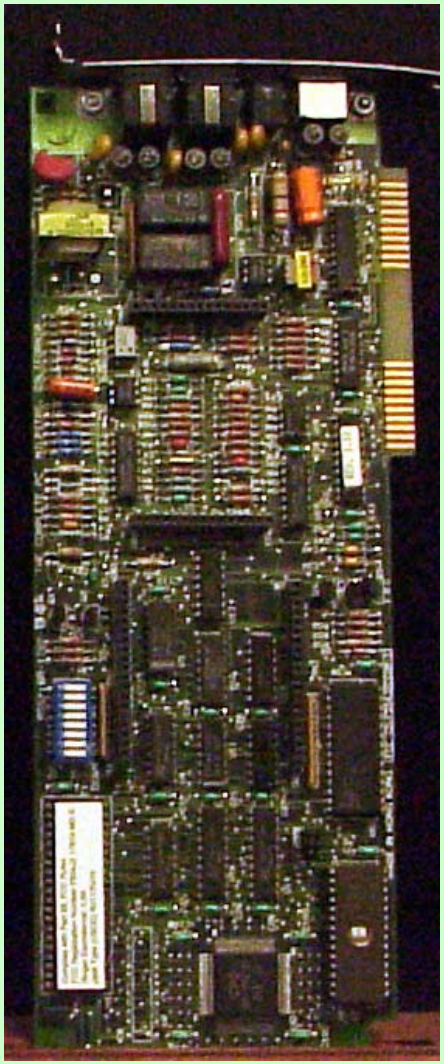
As the need for more function in less space increased, industry began to use analog components formed in a “hairpin” configuration. This circuit card from a 70s vintage VCR is an early example of this type of alternative, high density packaging.

In work

Large Scale Integration (LSI) (400-4,000 transistors per IC with 48 I/Os)

Hand Calculator

Was (Early 80s)



Component Types:

Mixed technology surface mount and through hole

Assembly Methods

Double sided pick and place, reflow, machine assembly and wave soldering

Design Methods

CAD design, multi-layer layout

Average Density

15 components per square inch

PCB Fabrication

Multi-layer (4), through hole with minimum line space of .015”

Board Description

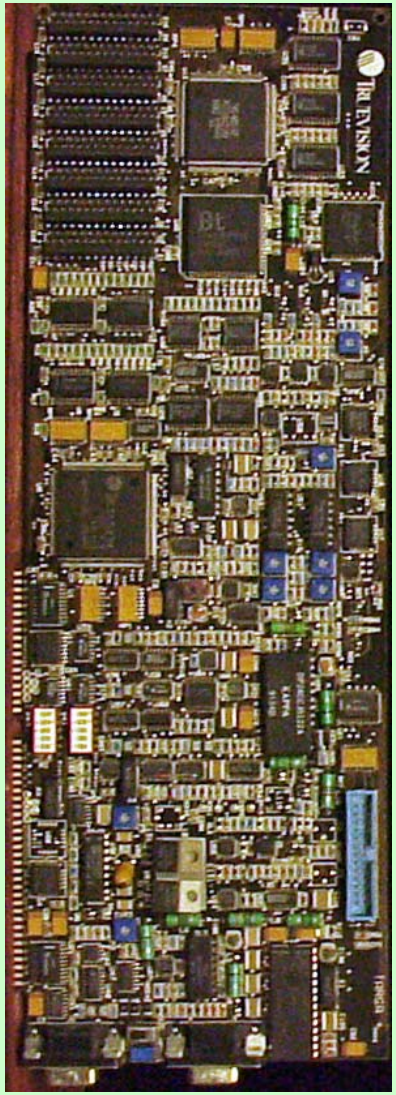
By the 80s, the first surface mount components moved from the R&D labs to commercial manufacturing. Change was slow at first because of component availability and cost. This PC modem card has only one surface mount device, a 100 pin QFP. A more significant innovation during this period was the widespread use of multi-layer printed circuit boards, improvement to the raw board manufacturing process drove the cost down and made it affordable for commercial applications.

In work:

Very Large Scale Integration (VLSI) (4,000-3000,000 transistors per IC with 64-300 I/Os)

Microprocessor

Was (Late 80s)EOS spacecraft



Component Types:

Mixed technology surface mount and through hole

Assembly Methods:

Pick and place, reflow, machine

assembly and wave soldering

Design Methods:

CAD design, multi-layer layout

Average Density:

20 components per square inch

PCB Fabrication:

Multi-layer (6), through hole with minimum line space of .010”

Board Description:

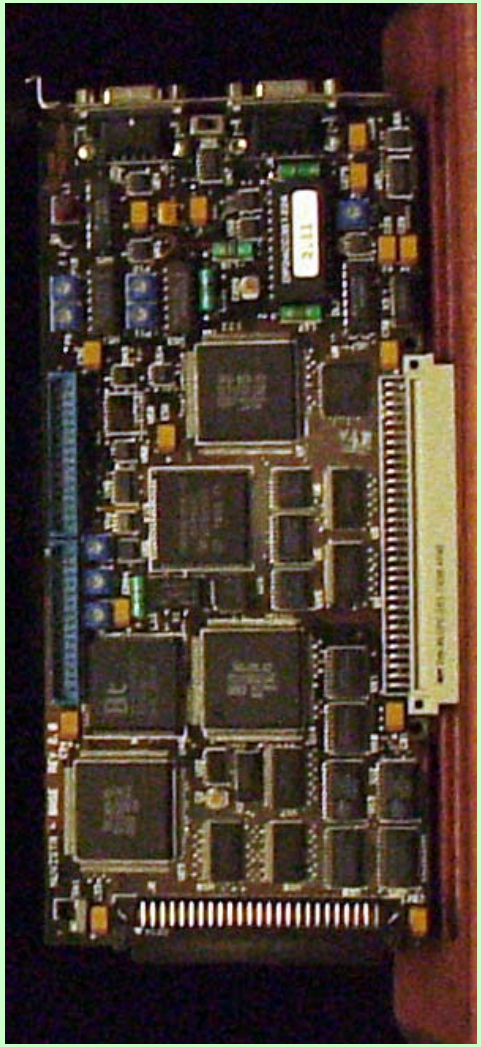
Throughout the 80s, component manufacturers continued to tool-up for surface mount packages, and by the late 80s, parts were readily available at competitive prices. Additionally, the pin counts on the digital devices continued to climb. It was now commonplace to see large scale integration with a pin count, or IO, of 160 to 200 for a single device – double the IO count from the early 80s. This video capture card has three large-scale integrated devices.

In Work:

Ultra Large Scale Integration (ULSI) (over 3000,000 transistors per IC with 300+ I/Os)

Small Computer

Was (Early 90s) New explorer spacecraft



Component Types:

Mixed technology surface mount and through hole

Assembly Methods

Pick and place, reflow, machine assembly

and wave soldering

Design Methods

CAD design, multi-layer layout

Average Density

25 components per square inch

PCB Fabrication

Multi-layer (4), through hole with minimum line space of .010”

Board Description

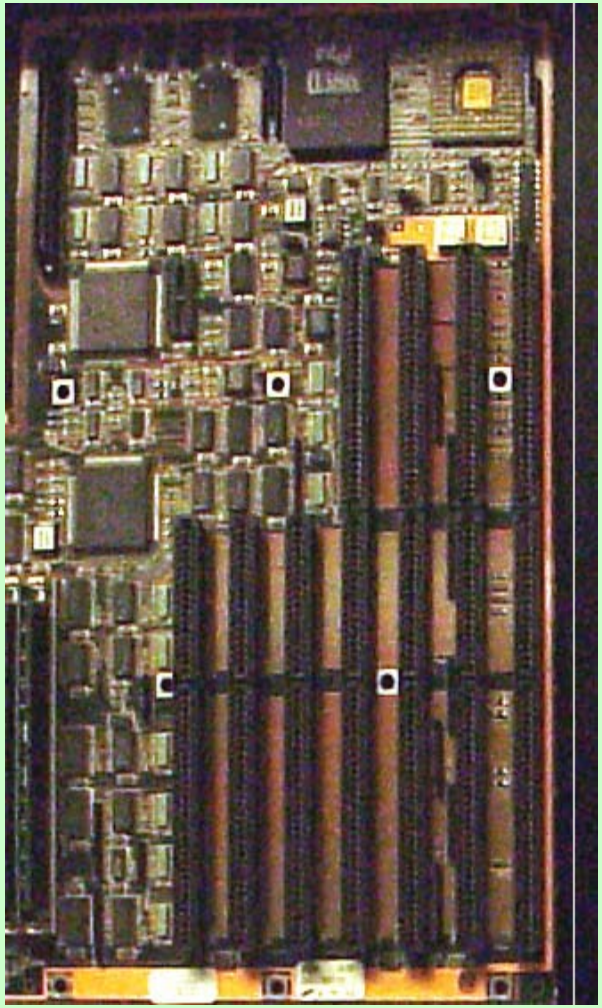
The need to maximize circuit card real estate drove the industry to develop the automated double-sided process, the analog components are mounted on one side and the digital parts are mounted on the other. This video card is an excellent example of double sided technology maximizing the available real estates.

In Work:

Gigascale Integration (GSI) (1 billion transistors per IC with 10,00+ I/Os)

Supercomputer

Was/Is (Late 90s early 2000s)
2nd Generation, Shuttle Avionics, NGST



Component Types:

Mixed technology surface mount and through hole

Assembly Methods:

Pick and place, reflow, machine assembly and wave soldering

Design Methods:

CAD design, multi-layer layout

Average Density:

30 components per square inch

PCB Fabrication:

Multi-layer (8), through hole with minimum line space of .005”

Board Description:

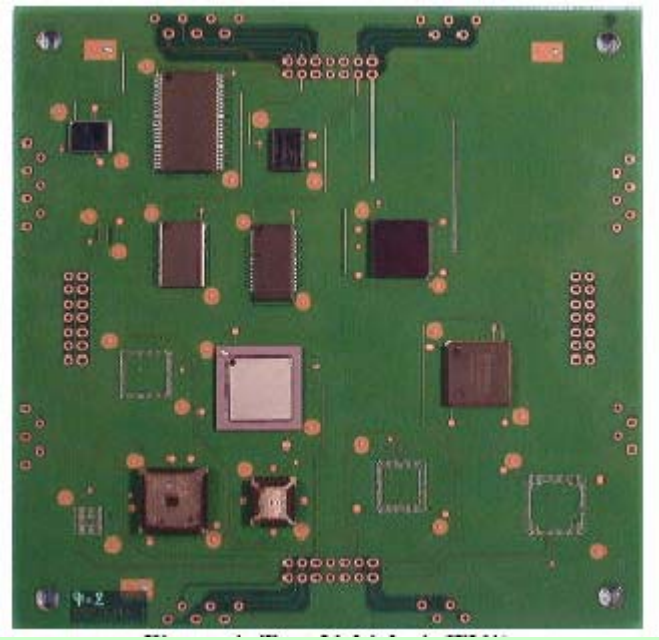
By the late 90s manufacturers were looking to drive the cost out of the products by reducing the installed number of semi-conductors per assembly. This was accomplished by incorporating very large interaced device or VLSI chips with O/I counts of 500 or more in Ball Grid Array packets .

In Work:

System on Chip (SOC) and System-In-Package (SIP)

Combination of discrete components, semiconductor, and PWB integrated on a single semiconductor chip

Will be (2007 +)Micro Satellites



Component Types:

Surface mount, circuit in board, circuit as a board

Assembly Methods

Chip on board leading to Chip scale packaging (CSP)

Design Methods

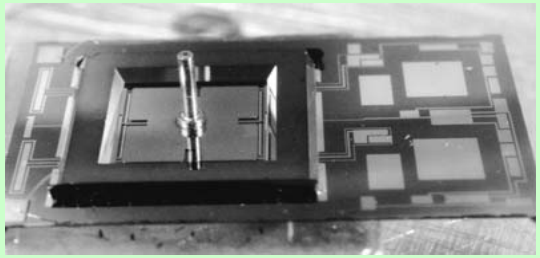
CAD design

Average Density

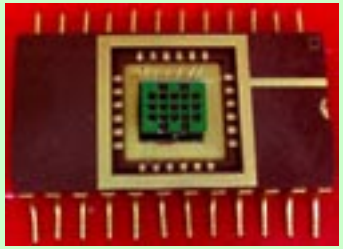
Integration of microelectronics, photonics, RF, and MEMs into a system.

In Work

Spacecraft on Chip (SOC)



MEMS Microgyro



MEMS Microthruster Propulsion System

SOME DIMENSIONS OF THE DILEMMA

- **How do we select the best technology level?**
  - ✓ **Are our people trained in and confident of the technology?—its limits, its demonstrated maturity, its design and testing tools, its software, etc.**
  - ✓ **Are our suppliers ready to propose using the level of advanced technology?—Have they products already developed which provide a base, are their internal skills and systems honed to this level?**
  - ✓ **How do our people specify the level of technology in an RFP? If we specify too tightly, will we restrict competition, will we stifle extant systems?**

MORE DIMENSIONS OF THE DILEMMA!

- **The electronics technology advancement curve determines the size of environmental "boxes", the lengths of cable runs, the convenient placement of components for repairs, etc.**
- **All of these affect weight, power requirements, logistics and servicing plans, lifetime of systems, etc.**
- **Additionally, wrong choices mean "dead ends" for protocols, established new integration possibilities, improved telemetry for reliability growth, etc.---remember and avoid: "ADA"**

SO HOW DO WE IMPROVE AND INSTITUTIONALIZE THIS ISSUE.

Some Holistic Solution Components

- **Recognize the full dimensions of the issue and talk about the cost and the issue: "less throw weight for Aries, lower safety, higher life cycle costs, etc.**
- **Create an inter-center team to evaluate advanced technologies from other sources: military advances, major civil market thrusts (eg.UAV's), overseas competition—other international space and aeronautical institutions.**
- **It is not enough to broaden the internal NASA "design teams" technology awareness—look to total process!**

MORE HOLISTIC SOLUTION ELEMENTS

- **Include our classical industrial support teams in the education process: i.e. pre-solicitation conferences, past performance criteria (that includes expertise in advanced technology levels and introduction of innovation, etc.**
- **Recognize the leverage that <u>small business</u> projects and ongoing SBIR and project teaming brings to NASA.**
- **Even in the face of massive budget shortfalls, maintain some select advanced technology development projects: i.e. willingness to embrace friction welding, also we can't let advanced technology be led by international competitors (we have all seen international "offsets"– <u>demand U.S. equivalents</u>).**

MORE HOLISTIC SOLUTION ELEMENTS

- **"Stretch the Stretch Requirements Initiative": this vital innovation should endure throughout the multi-decadal life of the Exploration Project.**
  - ✓ **Define block upgrade schedule opportunities for Exploration projects—a tailored NASA version of "Spiral Development".**
  - ✓ **Technology advancement plans. Consider technology exchange opportunities with industry.**
  - ✓ **Life cycle cost and reliability analysis tools that recognize the future penalties of obsolescence.**
- **Remain vigilant to the cost and failure potential of demanding that technology be on the impossible edge!**

SOME DO NOTS!

- **Do Not let the siren call of advanced technology turn NASA into a “Non Obtainium” project organization.**
- **Avoid the concept that NASA must ensure that all key technologies must be developed and advanced “in house”. The entire Exploration budget would not touch the investment made by computer industry companies.**
- **Do not create technology “police” within NASA.**

CONCLUSIONS AND SUMMARY

- **NASA must be intimately aware of the speed, direction, and advantages of advanced technology.**
- **NASA must have the internal processes and controls to turn the above knowledge into realistic, safe, cost-effective systems for all of its missions. This is particularly important for Exploration because of its clear multi-decadal future and daunting challenges.**
- **The solutions to this issue must be holistic, we have suggested a range of initiatives for consideration by the agency.**
- **NASA cannot fall behind the rest of the world in the use of advanced technology—but it must not fail because of overreaching.**