A Vision for Reflector Technologies

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Technology Mainstream

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Technology Headwater

An Opening Note of Precaution: Technological Parochialism. . .

optimum design\’ap-tə-məm di-’zīn\ *n* (2003): the design that is considered to be equally offensive by all subsystem engineers

Presented at the First “Loya Jirga,” May 1, 2003

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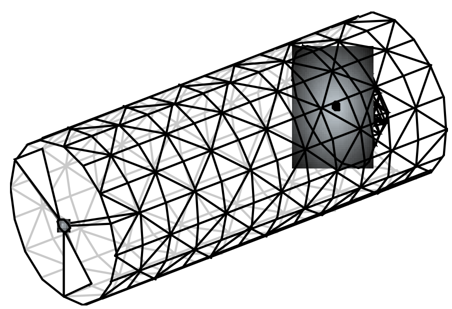

Structural engineer’s optimum design

Presented at the First “Loya Jirga,” May 1, 2003

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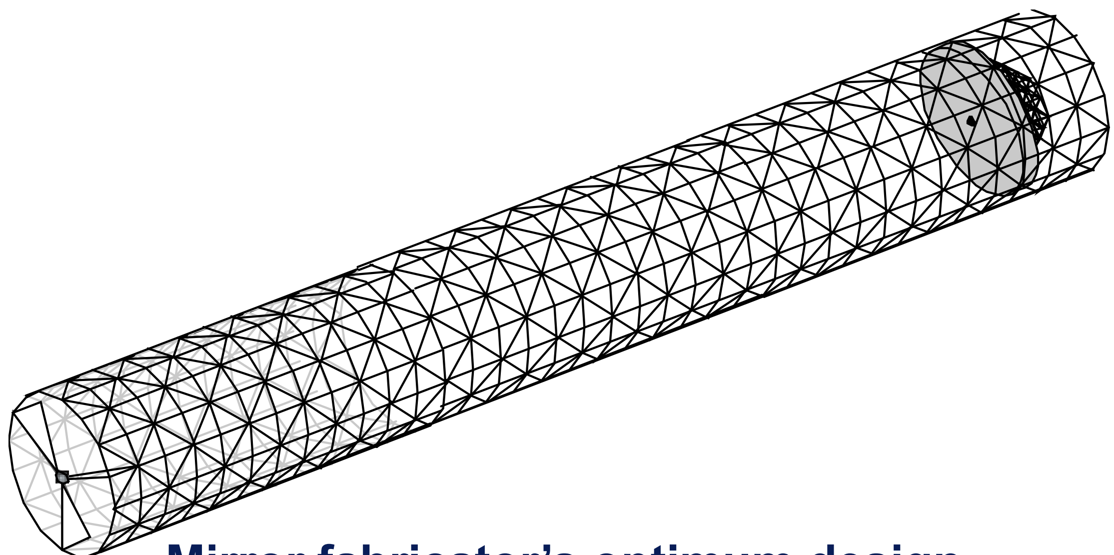

Mirror fabricator's optimum design

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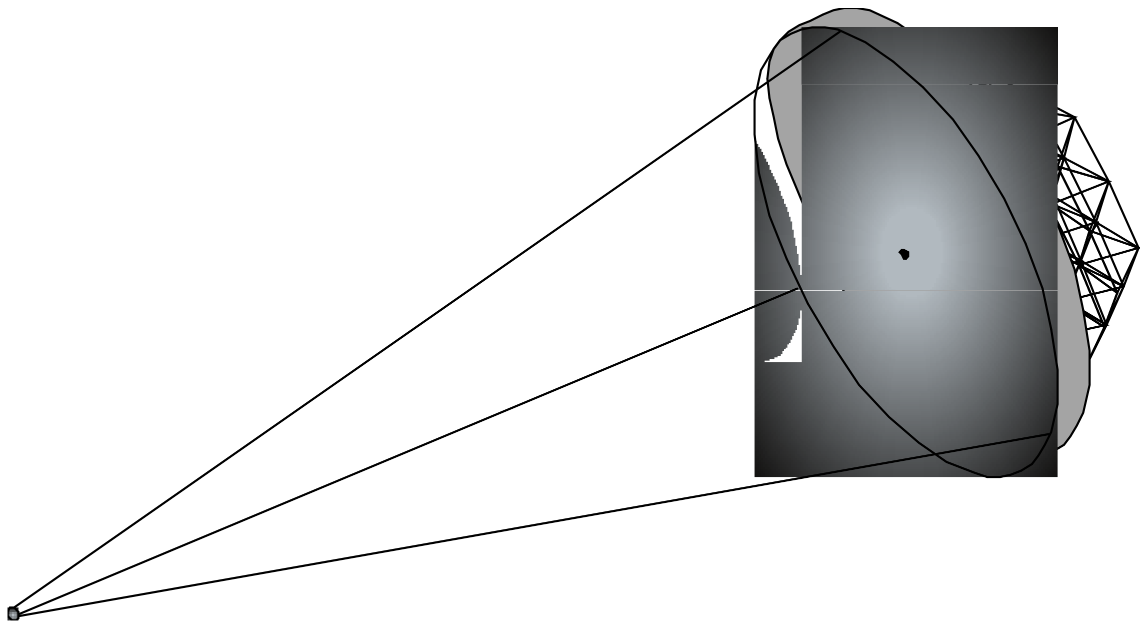

Astronomer's optimum design

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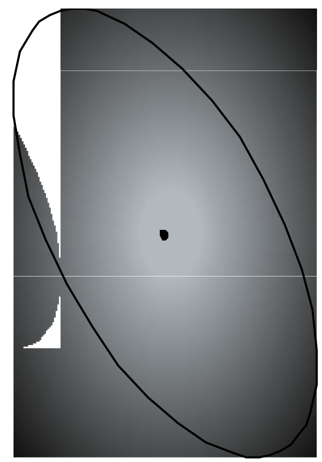

Control system engineer's optimum design

Presented at the First "Loya Jirga," May 1, 2003

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optimum design \'äp-tə-məm di-'zīn\ *n* (2003): the design that is considered to be equally offensive by all subsystem en[...]

The most successful designs will "spread the pain" between the subsystems and technologies.

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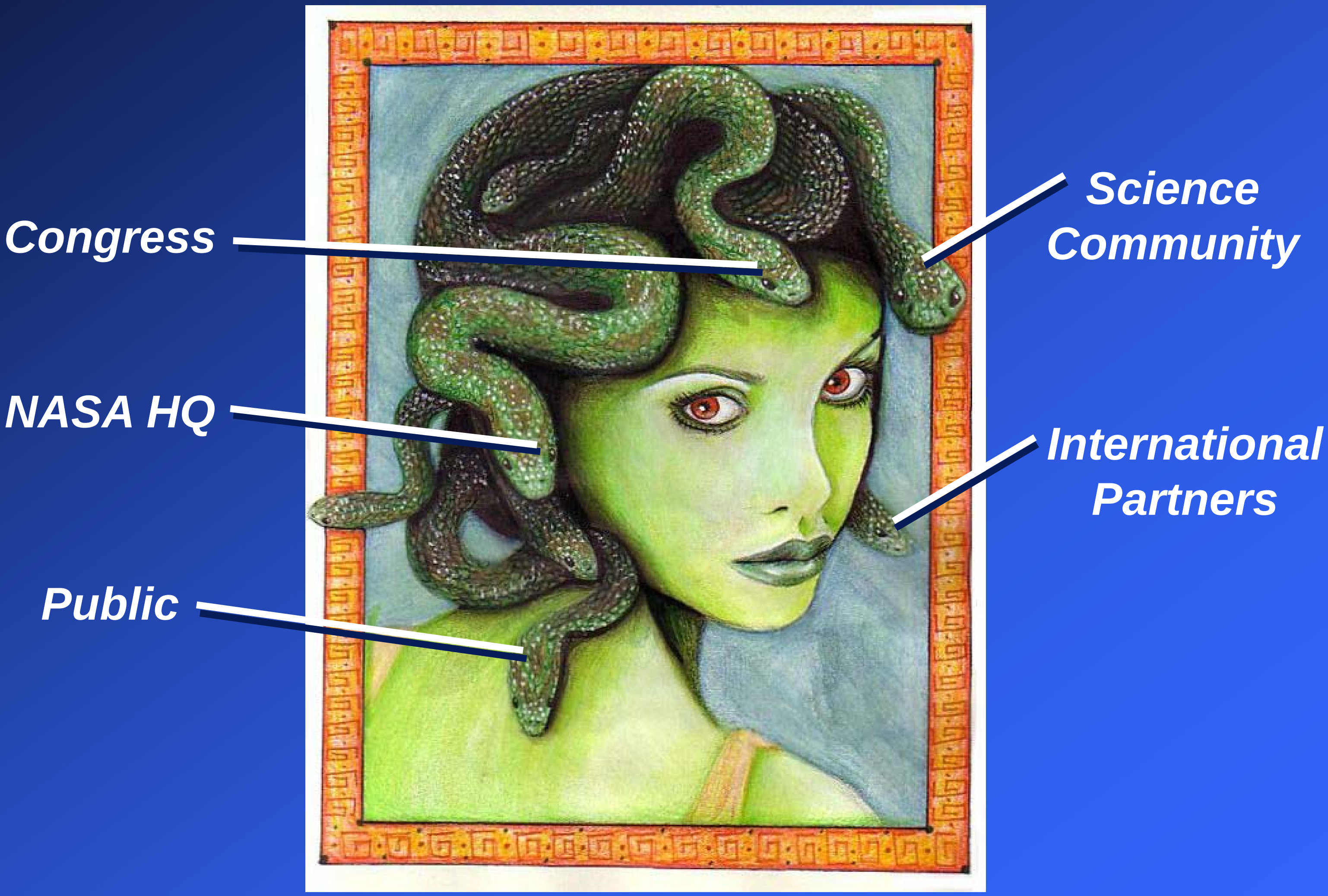
The Faces of the Customer

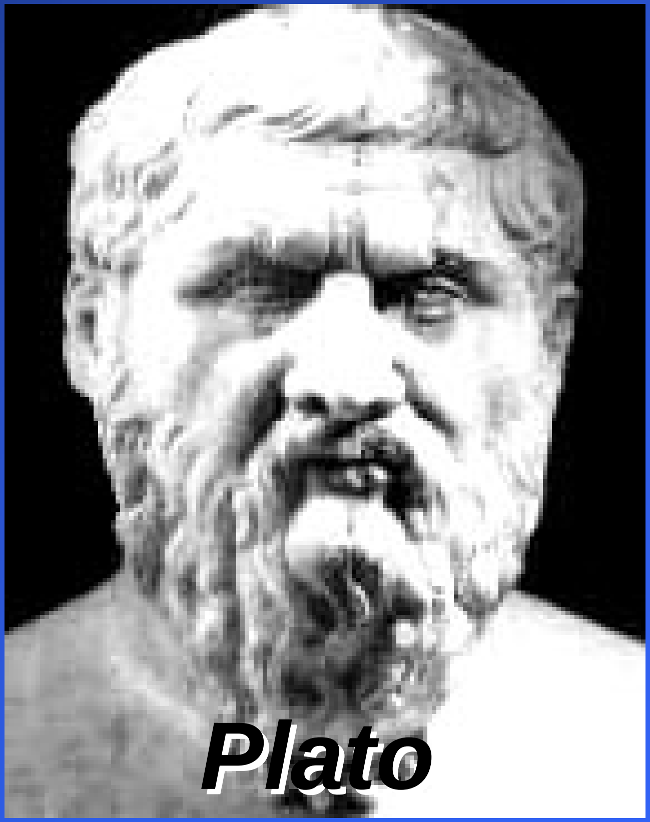


The Customer Has No Interest in Technology

- **Small, high-tech business rule No. 1:**

  Customers don't care about technology - they care about cost and functionality.

- **If there is no definable need, there is no value in the technology. . .**



"Necessity is the mother of invention." [NOT vice versa]

What Attributes Does the Customer REALLY Want?

- **Functionality:**
  - Reliability
  - Capability (increasing, *rather than decreasing*, in time)
  - Accessibility (by the customer)
- **Cost:**
  - Consistency (with functionality)
  - Predictability (in cost and development schedule)
  - Contain-ability
- **Other attributes that might affect engineering design:**
  - Integral to a higher agenda (e.g., tie to Exploration Initiative)
  - Revolutionary science (e.g., calibration with ground-based observatories)
  - Inspiration (e.g., human involvement?)

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But how do we map technologies to these attributes?

Cost vs. Benefit Analysis
(Active Control System)

Wavefront-Control Requirement

Disturbance Load (g's)

$$x_{rms} \propto \frac{a_{rms}}{(\zeta f^2)} \propto \frac{a_{rms}}{(\zeta)} \left[\frac{D^4}{\eta h^2 (E/\rho)} \right]$$

PSD of Structural Control System

Active Structural Control (Damping)

Passive Response of Structure

D = mirror diameter

h = structural depth

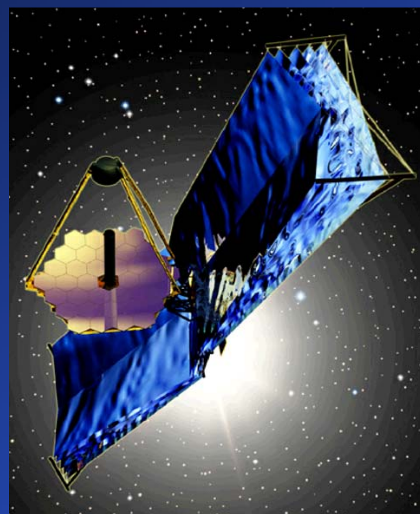
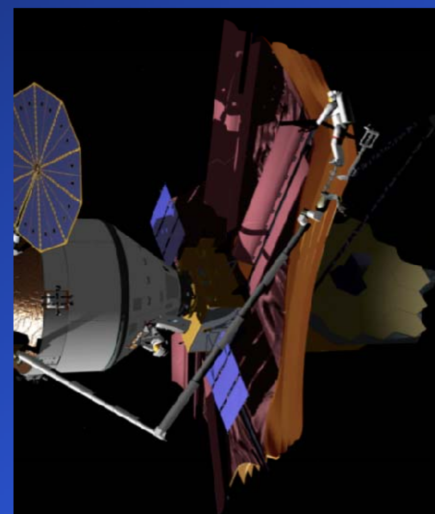
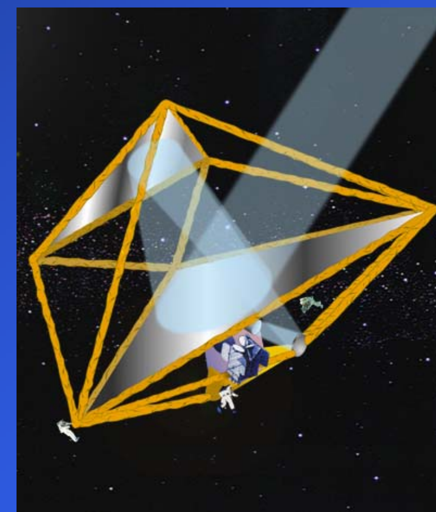
η = structural mass fraction

E/ρ = material specific stiffness

Lake, M. S., Peterson, L. D., and Levine, M. D.: "A Rationale for Defining Structural Requirements for Large Space Telescopes," *Journal of Spacecraft and Rockets,* Vol. 39, No. 5, Sept-Oct., 2002

Simple performance models are critical to a thoughtful cost vs. benefit analysis of competing/complementary technologies

Engineering Reality: Flexible Mirrors Demand Intelligent Systems of Increasing Complexity

HST	**JWST**	**SAFIR**	**DART**
D = 2.4 m	D = 6.0 m	D > 10 m	D > 25 m
$\rho \approx$ 200 kg/m^2	$\rho \approx$ 15 kg/m^3	$\rho <$ 10 kg/m^2	$\rho \sim$ 1 kg/m^2
$f_o \approx$ 100 Hz	$f_o \approx$ 10 Hz	10 Hz > f_o > 1 Hz	f_o < 1 Hz
Passive Stabilization	*Set-and-Hold Stabilization*	*Active Stabilization*	*Wavefront Correction*

Does the Customer Care That the System Will Have Active Optics?

- **Functionality:**
  - Reliability
  - Capability (increasing, *rather than decreasin* … me)
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  - …
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NO!

But "Intelligent Technologies" Can Lead to Further Functionality That the Customer Wants

- **Reliability**
  - Health Monitoring/Management
  - Self-Healing Systems
  - Distributed and Redundant Systems
- **Capability (increasing, rather than decreasing, in time)**
  - Re-Programmable Software
  - Re-Programmable Hardware (e.g., phase-change materials and morphing systems)
  - On-orbit Repair/Upgrade
- **Accessibility (by the customer)**
  - Ease of access (think *iTelescope*!)
  - Web-based interfaces to involve public in studying science AND operations information

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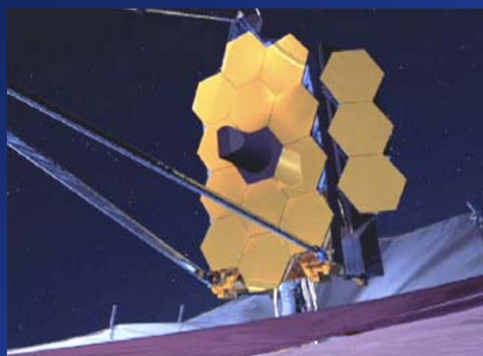
- **Capability** [illegible] time)
  - Re-Pr[illegible]
  - [illegible]rphing
    syst[illegible]
  - On-orb[illegible]
- **Accessibility (**[illegible]
  - Ease of acces[illegible]ink *iTe*[illegible])
  - Web-based interfaces to [illegible]e public in [illegible]ing science AND operations information

"Mapping back" helps ensure technology adoption and can lead to expanded opportunities

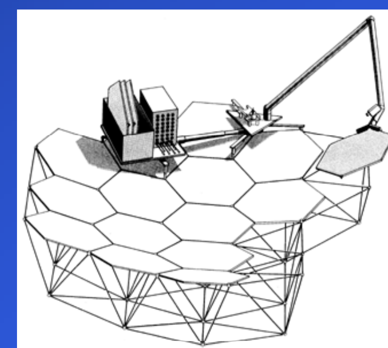
Cost vs. Benefit for Automated Assembly and Maintenance?

Mechanization



Astronaut/Teleoperati

Automation



10^1 (JWST) 10^2 (HST, SAFIR) 10^3 10^4

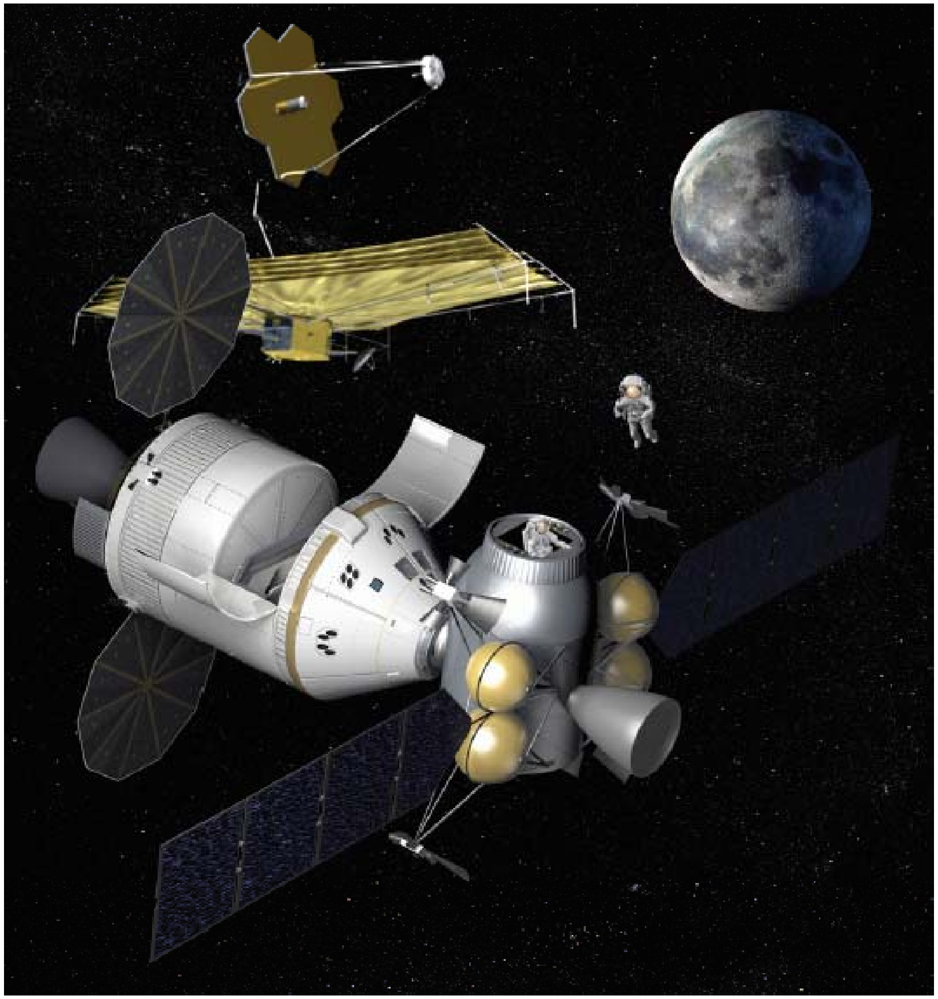
Number of Assembly/Maintenance Tasks

Automation is costly, but can drive total cost down if it improves launch efficiency AND enables maintenance

Lake, M. S.: *"Launching a 25-Meter Space Telescope: Are Astronauts a Key to the Next Technically Logical Step After NGST," presented at* Presented at the 2001 IEEE Aerospace Conference, IEEE Paper No. 460, Big Sky, Montana, March 10-17, 2001

Connection with a Higher Agenda:
Another Attribute That Affects Technology Adoption

Future major science facilities in space will be extremely challenging. Humans and robots on site are likely to be necessary if these missions are to be successful.



A cis-lunar "sortie:" one FISO concept for servicing the ~ 10 m SAFIR observatory at the Earth-Moon libration point using an augmented *Orion* and LSAM crew module.

(H. Thronson, 5/07)

The Most Critical Attribute?

- **Functionality:**
  - Reliability
  - Capability (increasing, *rather than decreasing*, in time)
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- **Cost:**
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What Will the Customer Do to Address Cost?

- **Consistency (with functionality)**
  - Exploit intelligent-system technologies to maximize functionality?
  - Develop volumetrically efficient packaging schemes (minimize launch cost)
  - Appropriate use of automation / teleoperation for deployment and maintenance
- **Predictability (in cost and development schedule)**
  - Guide technology-development with proper metrics from system analyses
  - Determine early the Cost vs. Benefit, and track over time
  - Invest in multiple solution paths
- **Contain-ability**
  - Exploit cost-sharing from other enterprises or sources
  - Employ "cost-driver" analyses to assess operations

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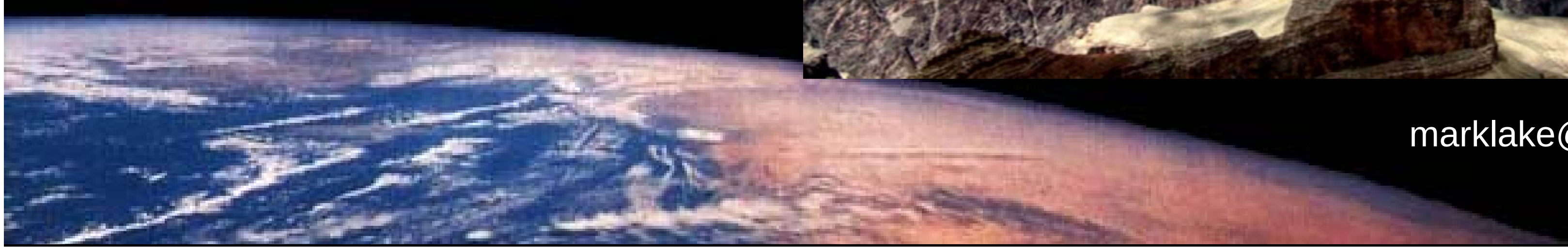
Which is the Better Precedent for Future Space Telescope Systems?

Summary - Isn't This the KISS Mission?



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