Examination of Prospects for Satellite Servicing

A Common Government/Industry Strategy for the Development of Space

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Contents

Page 3: Introductory Framework (5 charts)

Page 9: Industry Interview Results

- Page 10: Introduction (4 charts)
- Page 15: Business - Questions & Responses (6 charts)
- Page 22: Technology - Q & R (4 charts)
- Page 27: Government - Q & R (1 chart)
- Page 29: On-orbit Infrastructure - Q & R (4 charts)
- Page 34: Satellite Servicing - Q & R (9 charts)

Page 44: Summary of Findings (5 charts)

Page 50: Recommendations (1 chart)

Introductory Framework

Premises

- Satellite industry established by governments during the 1960s.
- Government (NASA-"NEXT/RASC;" OSD/DoD/DARPA -"Orbital Express," etc.) at cross-roads considering 21st century space investments.
- $80 billion satellite industry at cross-roads considering 2000s growth prospects.
  - Viability weakening (unfavorable regulatory and competitive environment - terrestrial fiber, foreign encroachments, etc.)
- A robust, 21st century satellite servicing industry sector is a potential emerging prospect.

Definition

Satellite Servicing implies the offering of services to satellite owners or operators that involve the direct manipulation of spacecraft hardware or assets on-orbit for the purposes of refueling, upgrade, repair, inspection, relocation, burial, etc.

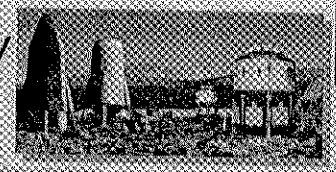
Stepping Stones

Satellite Servicing – The Next Step

Build a strong Economic Foundation extending to edge of Van Allen Belts

Beyond

Sustainable Planetary Surfaces

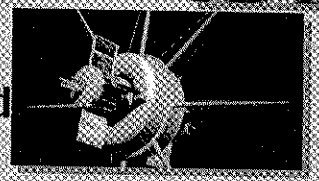


- Traveling out to ~1.5 AU, and beyond
- Staying for indefinite periods
- Enabling sustainable scientific research
- Living and working on another planet

Accessible Planetary Surface

- Traveling out to 1.5 AU
- Staying for 1-3 years
- Enabling tactical investigations
- Visiting and working on another planet

Earth's Neighborhood

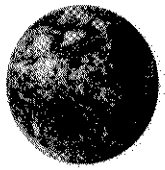


- Traveling up to 1.5 million km
- Staying for 50-100 days
- Enabling huge optical systems
- Living in deep space

Economic Foundation

- Gov't/Industry Partnership
- Establish LEO-to-GEO Satellite Servicing Industry Infrastructure

Earth and LEO

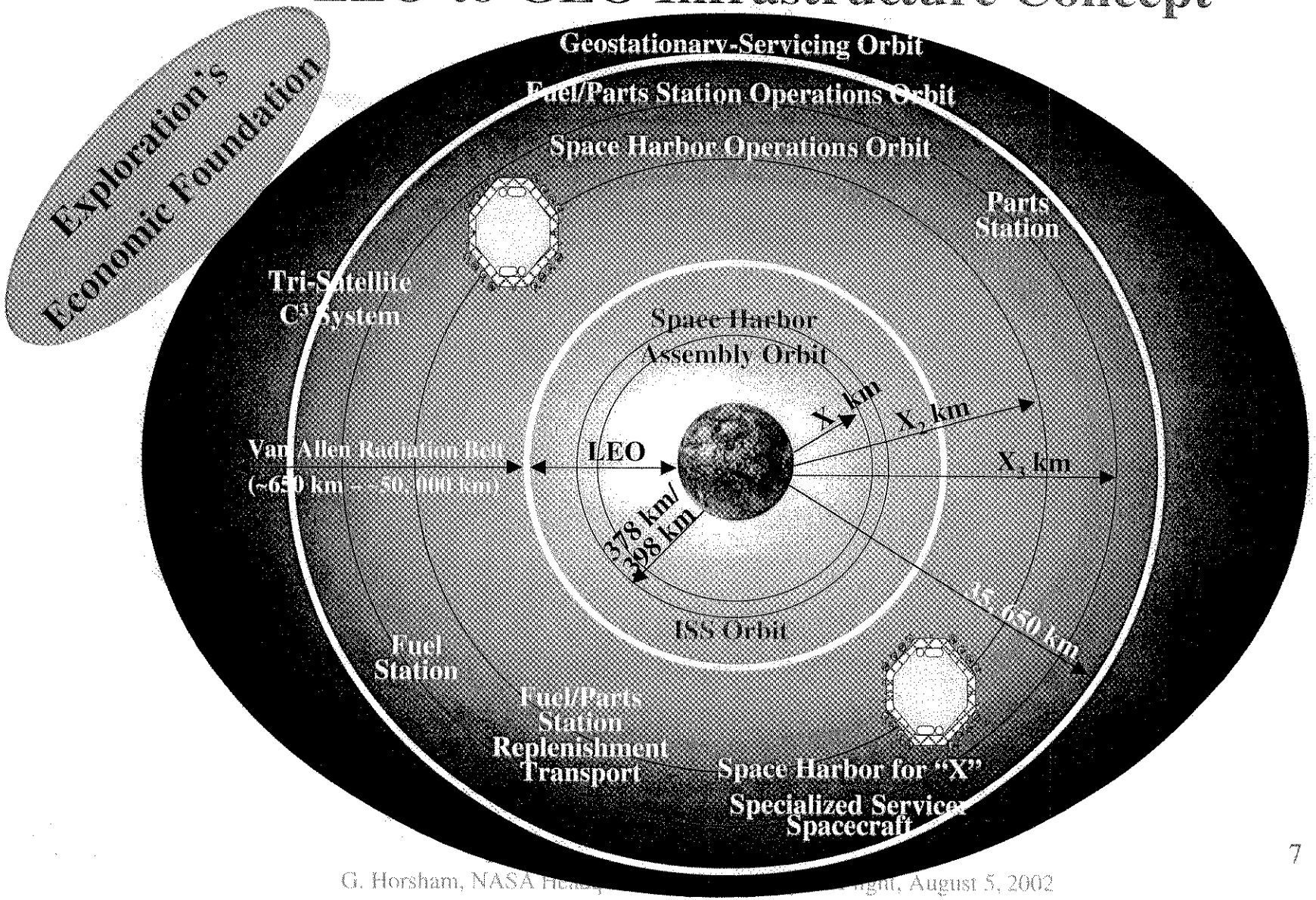


- Space Station experience
- Solar System learning
- Technology advancements

Science Driven
Technology Enabled
Economics Supported

Satellite Servicing

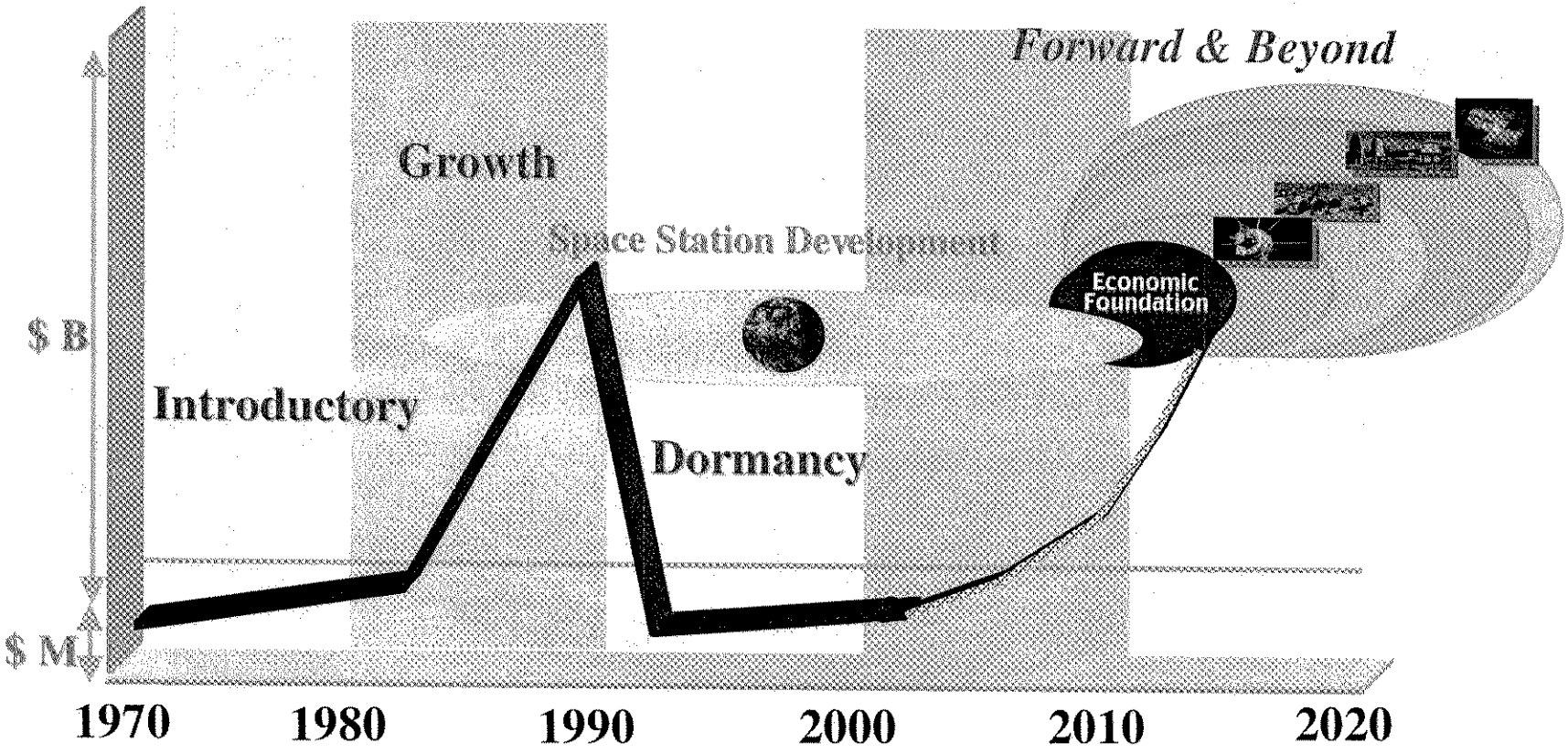
LEO-to-GEO Infrastructure Concept



Satellite Servicing

Investment Profile

(Qualitative/Not to Scale)



Industry Interviews

conducted between
May 4, 2002 and July 6, 2002

Interview Results

All Interviews were conducted at Interviewee's Company Location

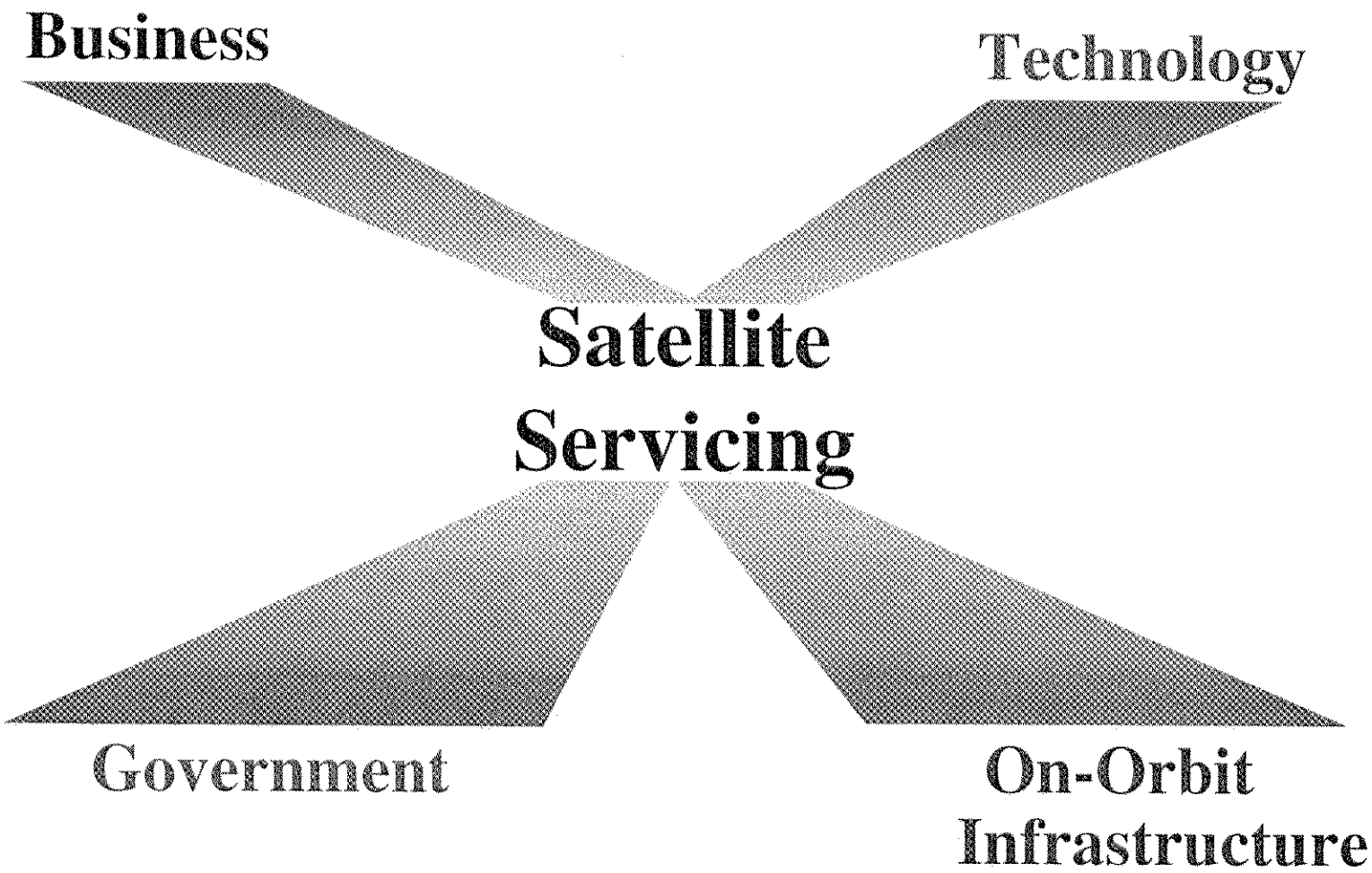
Introduction

Interviewees

1. **Ben Chang, Ph.D.,** Vice President, Satellite Engineering and Program Development, Intelsat
2. **James Crocker,** Vice President, Space Exploration Systems, Lockheed Martin Corporation
3. **Bruce McCandless II,** Chief Scientist, Resuable Space Transportation Systems, Lockheed Martin Corporation
4. **Laurence Price,** Director, Crew Return Vehicle, Lockheed Martin Corporation
5. **Steven Keppers,** XSS-11 Program Manager, Lockheed Martin Corporation
6. **Peter Hadinger,** Chairman, Satellite Industry Association; Director, Telecommunications Policy, TRW
7. **Richard Dalbello,** Executive Director, Satellite Industry Association
8. **Dave Akin, Director,** Space Systems laboratory, University of Maryland
9. **Maj James Shoemaker, USAF, Ph.D.,** Program Manager, Orbital Express, DARPA
10. **Rud Moe,** Program Manager, Hubble Space Telescope, NASA Goddard

Question Categories

Five-dimensional Assessment



Question Subcategories

Business	Technology	Government	On-orbit Infrastructure	Satellite Servicing
Economic Viability	Challenges	NASA Roles & Responsibilities	Future Commonality	Business Potential
International Environment	Applications		Roles & Responsibilities	Industry Needs
Challenges			Economic Utility	Satellite Evolution
Vision			Business Potential	Market Sectors
Competitive Needs				Market Segments
Technology Life Cycle				Key Technology
Trends				Location
				Logistics

Characterization of Responses

Encouraging - with some Concerns

Question Categories	RT: Responses Totals	WT: Weighted Totals	Characterization Ratings (WT/RT)
Business	[illegible]	[illegible]	3.1 Concerned
Technology	[illegible]	[illegible]	4.1 Encouraging
Government	[illegible]	[illegible]	3.6 Concerned & Encouraging
On-orbit Infrastructure	[illegible]	[illegible]	4.0 Encouraging
Satellite Servicing	[illegible]	[illegible]	3.9 Encouraging
Combined Avg. (E's & C's)	[illegible]	[illegible]	3.8 Encouraging

Positive (P) = 5 Encouraging (E) = 4 Concerned (C) = 3 Hesitant (H) = 2 Negative (N) = 1

Business

Questions & Responses

Business

Economic Viability

Question 1

Does the satellite industry believe that the current "build, launch, operate and replace (BLOR)" business model is satisfactory, sufficient and efficient, and should remain in place for the foreseeable future?

Aggregate Summary of 6 Responses

No confidence in long-term viability of current business model

- **Chronic overcapacity**
- **Launch and insurance costs**
- **Negative investment/market image**
- **Government stagnation**

Business

International Environment

Question 2

To what extent are other governments providing support to their satellite industry?

Europe Japan Russia China Other (Identify)

Aggregate Summary of 3 Responses

European and Chinese industries gaining significant advantage through government subsidies

Business

Challenges

Question 3

To what extent do the following factors drive decisions on satellite design & evolution?

- Reducing spacecraft cost
- Extending spacecraft life
- Reducing risk of spacecraft failure
- Improving spacecraft
- Performance/capabilities
- Strategic business plans/motivations
- Responding to competitors actions

Aggregate Summary of 3 Responses

Key Drivers

- Reducing spacecraft cost
- Strategic business plans/motivations

Business

Challenges

Question 4

Apart from lowering the cost per kilogram to orbit, have satellite owners/operators identified any other major obstacles to growth that are beyond the industry's risk threshold?

Aggregate Summary of 2 Responses

Cost and launcher payload size limitations

- **Forces premature application of new technologies**
  - **Increased risk of satellite failure**

Business

Question 5

Vision

Have satellite owners/operators/manufacturers formulated a collective vision of their industry's future growth prospects?

What is your vision of the commercial satellite industry's future growth prospects, and, do others share it?

Aggregate Summary of 6 Responses

Industry currently has no collective vision

- **Unable to discern growth-path**
  - **Survivalist instinct due to recent and severe, multi billion dollar investment and competitive failures**

Business

Technology Life-cycle

Question 6

At what age does a functioning satellite generally become technologically obsolete and what is the significance of this state from:

- A primary owner/operator standpoint?
- An aftermarket owner/operator standpoint?
- A manufacturer standpoint?

Aggregate Summary of 4 Responses

Owner: 7 to 12 years
Manufacturer: 3 to 5 years
Potentially viable aftermarket

Technology

Questions & Responses

Technology

Competitive Needs

Question 7

Name five specific spacecraft/satellite technology advancements, which if brought into service within the next 10 to 15 years, would provide a significant competitive advantage for the U.S. satellite industry?

Aggregate Summary of 3 Responses

- **Higher power** (Nuclear, Adv. Solar Cells & Batteries)
- **Higher bandwidth** (Laser/Optical)
- **Lower launch cost**
- **Lower operational cost**
- **Improved lifetime** (Electronics, E-Propulsion)

Technology

Trends

Question 8

Is satellite manufacturing (for GEOsats in particular) moving towards standardization? If not what is preventing the industry from moving in that direction?

Aggregate Summary of 4 Responses

- **Early-stage standardization at component level**
- **Customization of certain electronics and payload components resist trend**
- **Acceleration depends on new business paradigm**

Technology

Challenges

Question 9

Have satellite owners/operators/manufacturers identified any other major technological obstacles to growth that are beyond the industry's risk threshold?

Aggregate Summary of 2 Responses

- **Risky, capital-intensive image of launch**
- **Need for higher levels of autonomy**
  - **Reduction of operating cost without compromising safety**

Technology

Application

Question 10

How effectively do the needs or performance requirements of satellite owners/operators drive the evolution of satellites?

(Do they just restrict their systems to current technology?)

Aggregate Summary of 2 Responses

Owners/operators risk averse

- Adopt new technologies if
  - Technological risk minimized
  - Performance benefits clear

Government

Questions & Responses

Government

Question 11 NASA Roles & Responsibilities

What could NASA be doing to help the satellite industry achieve greater levels of market/economic performance in the future?

Aggregate Summary of 5 Responses

Invest in high risk, high payoff systems and technologies

- Establish laser/optical communications program
- Eliminate categorization of spectrum bands
- Initiate development of TDRS replacement
- Develop infrastructure with commercial potential
- Develop one reliable launcher for the future
  - while supporting current Atlas/Delta launch systems
- Serve as military-DARPA/commercial transition agent
- Address cost drivers for human systems

On-orbit Infrastructure

Questions & Responses

On-orbit Infrastructure

Future Commonality

Question 12

Considering the potential benefits of satellite servicing, the satellite industry's growth needs, and NASA's long-range exploration goals, what might be the common infrastructure needs between these two entities over the next 15 years?

Aggregate Summary of 3 Responses

- A civil-commercial servicing infrastructure
  - piggy-backed on Military-DARPA investment
- A market for rendezvous and docking technology
  - through establishment of standards

On-orbit Infrastructure

Future Commonality

Question 13

Given NASA's desire to build a stepping-stone to Lunar/Martian settlement within the next 30 to 50 years, and given the satellite industry's future market/growth interests, what do you think may be the common infrastructure needs over the next 15 years?

Aggregate Summary of 2 Responses

An integrated civil, commercial, military, space-based relay infrastructure, in addition to transportation and servicing

On-orbit Infrastructure

Question 14

Roles & Responsibilities

What should the roles and responsibilities of each of the following entities be in the establishment of a potential, future, on-orbit, commercial satellite servicing infrastructure?

- NASA
- The U.S. Satellite Industry
- Other U.S. Government Agencies
- Other Countries or Regional Economic Blocks

Aggregate Summary of 6 Responses

- **NASA:** takes lead, provides on-orbit infrastructure and risk capital/support R&D
- **Industry:** invest in standardization, develop servicer market, pay marginal cost to transport parts, pay usage fees
- **Other U.S.G. Agencies:** participate as partners
- **Other Countries/REAs:** seek roles in new industry sector development

On-orbit Infrastructure

Economic Utility

Question 15

Looking out around the year 2015, would the establishment of an on-orbit, commercial satellite servicing infrastructure be of potential high utility to satellite owners or operators?

Aggregate Summary of 3 Responses

Yes: once technological and business risks have been minimized

- Government established infrastructure
  - Robots: Human Supervision
  - Humans: Special Services

Satellite Servicing

Questions & Responses

Satellite Servicing

Business Potential

Question 16

At approximately what fraction of total asset value might satellite servicing be cost attractive to satellite owners or operators?

Aggregate Summary of 6 Responses

Between 25% and 60% of total asset value, which includes launch cost

- **Fraction tends to the high end of range depending on proximity to BOL and particular servicing objective**

Satellite Servicing

Business Potential

Question 17

What approximate increased premium might satellite owners/operators pay satellite manufacturers for a "serviceable" satellite if this option were available in the future?

Aggregate Summary of 4 Responses

None: not unless insurers or government provided serious incentives in terms of insurance or tax breaks.

- **A partnership between a leading manufacturer and an insurer in this vein might attract industry followers.**

Satellite Servicing

Industry needs

Question 18

Is robotic or human satellite servicing a capability that the satellite operators and manufacturers would like to see developed and economically maximized?

Aggregate Summary of 5 Responses

Yes: concerns about additional weight impact, payload accessibility/standardization, economic case, and developmental cost

- Industry would resist change
- Government must trigger market, pay developmental or non-recurring cost
- Insurers should provide reduced rates incentives
- Servicing most desirable near BOL
- Lowest cost for same reliability

Satellite Servicing

Satellite Evolution

Question 19

How might satellites change to exploit or take advantage of on-orbit servicing, if the price were right?

Aggregate Summary of 3 Responses

- Components/Interfaces Standardized
- Component accessibility increased
  - Heavy bolting reduced
- Fuel access ports incorporated
- Docking and rendezvous aids incorporated

Satellite Servicing

Market Sectors

Question 20

If satellite servicing became a reality around 2015, where would the market be?

- GEO only
- GEO and MEO only
- GEO, MEO and LEO

Aggregate Summary of 5 Responses

GEO, MEO and LEO

- **GEO Market:** Life extension awaiting replacement
- **LEO Market:** disposal of Russian nuclear satellites
- **Competition:** Replacement
  - Replacement becomes less economical as scale and/or capitalization increases

Satellite Servicing

Question 21

Market Segments

If robotic satellite servicing were made to exist between 2010 and 2015, which of the following on-orbit, commercial satellite servicing capabilities might be of the most interest economically to the satellite owners or operators?

Inspection	Upgrade	Maintenance	Other
Refuel	Reboost	Replacement	
Repair	Retrieve	Rehabilitation	

Aggregate Summary of 6 Responses

Top four: Refuel, Upgrade, Repair, Inspection.

- **Added: Relocation (GEO), Burial (GEO)**
  - **Critical Technologies: dexterous repair and rendezvous and grapple**

Satellite Servicing

Key Technology

Question 22

What would be the best means by which to most effectively (cost and performance-wise) accomplish on-orbit satellite servicing?

- Robots (Fully autonomous)
- Tele-robots (Semi-autonomous – i.e., ISS astronaut/ground controlled robots)
- Astronauts
- Other

Aggregate Summary of 6 Responses

Tele-robotics (Consensus)

- **Scenario Options:** ground-based operator, ground-based line-of-sight operator, space-based operator
  - **Human function:** operate/supervise, intervene if robot cannot perform task

Satellite Servicing

Location

Question 23

Where should satellite servicing be performed for maximum efficiency?

- At their orbital stations
- Away from their orbital stations

Aggregate Summary of 5 Responses

Orbital station (Consensus)

- Line-of-sight control to minimize GEO-to tele-operator time-delay
- Should not interfere (EM/RF) with nearby satellites
- Transporting elsewhere, especially LEO, too energy intensive

Satellite Servicing

Question 24

Logistics

If satellite servicing became a reality, where would you expect satellite supplies (fuel, replacement parts, etc.) to be stored?

- On-orbit
- On the ground (i.e., launched on demand)

Aggregate Summary of 4 Responses

- **On-orbit:** Fuel, other commodity replacement parts
  - Under-utilized launchers could be used for low-cost, depot resupply missions
- **Ground:** Special order parts

Summary of Findings

Summary of Findings

Business

1 **Economic Viability:**

- **No confidence in long-term viability of current business model.**

2 **International Environment:**

- **European and Chinese industries gaining significant advantage through government subsidies.**

3 **Challenges:**

- **Reducing spacecraft cost; Strategic business plans/motivations; Cost and launcher payload size limitations.**

4 **Vision:**

- **Industry has no collective vision - unable to discern growth-path.**

Summary of Findings

Technology

1 Competitive Needs:
- Higher Power (Nuclear, Advanced Solar cells & Batteries), Higher Bandwidth (Laser/Optical Communications),
- Lower launch cost,
- Lower operational cost,
- Improved lifetime (Electronics, E-Propulsion)

2 Trends:
- Standardization.

3 Challenges:
- Risky, capital-intensive image of launch; Need higher levels of autonomy.

4 Application:
- Owners/Operators risk averse.

Summary of Findings

Government

1 NASA Roles & Responsibilities:

- **Invest in high risk, high payoff systems and technologies.**

Summary of Findings

On-orbit Infrastructure

1 **Future Commonality:**

- **Military-civil-commercial servicing infrastructure.**
- **Integrated civil, commercial, military, space-based relay infrastructure.**
- **Transportation infrastructure.**

2 **Roles & Responsibilities:**

- **NASA takes lead - invests in high risk infrastructure.**
- **Industry invest in standardization; pays marginal costs and usage fees.**

Summary of Findings

Satellite Servicing

1 **Business Potential:**

- **Cost attractive at 25% to 60% of total asset value.**
  - **High-end BOL bias**

2 **Satellite Evolution:**

- **Components/Interfaces Standardization**
- **Component accessibility**
- **Fuel Access Ports**
- **Docking and Rendezvous aids**

3 **Market Sectors:**

- **GEO, MEO and LEO**

Summary of Findings

Satellite Servicing (Continued)

4 **Market Segments:**

- **Refuel, Upgrade, Repair, Inspection**
  - **Added: Relocation (GEO), Burial (GEO)**

5 **Key Technology:**

- **Tele-robotics.**

6 **Location:**

- **Orbital station.**

7 **Logistics:**

- **On-orbit storage of fuel and other commodity replacement parts**
- **Ground storage of special order parts.**

Recommendations

1. Introduce NASA's new management team to the prospects for satellite servicing.
2. Introduce the Aerospace Commission to the prospects for satellite servicing, for possible policy considerations.
3. Establish satellite servicing as a potential key component of NASA's exploration strategy.
4. Initiate the building of a partnership with DARPA in the area of satellite servicing.
5. Engage the Satellite Industry Association (SIA) in regularly scheduled, bi-annual forums for dialogue about industry plans, outlook, issues and concerns.
6. Conduct a broad, national and international review of the satellite industry's perspectives, as it relates to establishing a 21st century satellite servicing industry sector.
7. Conduct a series of annual, international conferences or conference sessions for government, industry, and academia to exchange ideas and build consensus.
8. Conduct a broad review to gauge the developmental status/readiness of satellite and satellite servicing technologies for strategic investment purposes.