https://ntrs.nasa.gov/search.jsp?R=20200000414 2020-05-10T02:01:43+00:00Z

Space Science and Technology Partnership Forum: Integration with Commercial In-Space Assembly Activities

Gregory Benjamin and Alejandro Pensado

Analytical Mechanics Associates, Inc.

Dale C. Arney, Ph.D., Sharon A. Jefferies, Matthew A. Stafford, Frederic H. Stillwagen, and Phillip A. Williams, Ph.D.,

NASA Langley Research Center

Erica Rodgers, Ph.D., *NASA Headquarters*

Joseph Fulton, *University of Maryland at College Park*

Nicholas M. Houghton, *Michigan State University*

Alexander Mazarr, *Virginia Polytechnic and State University*

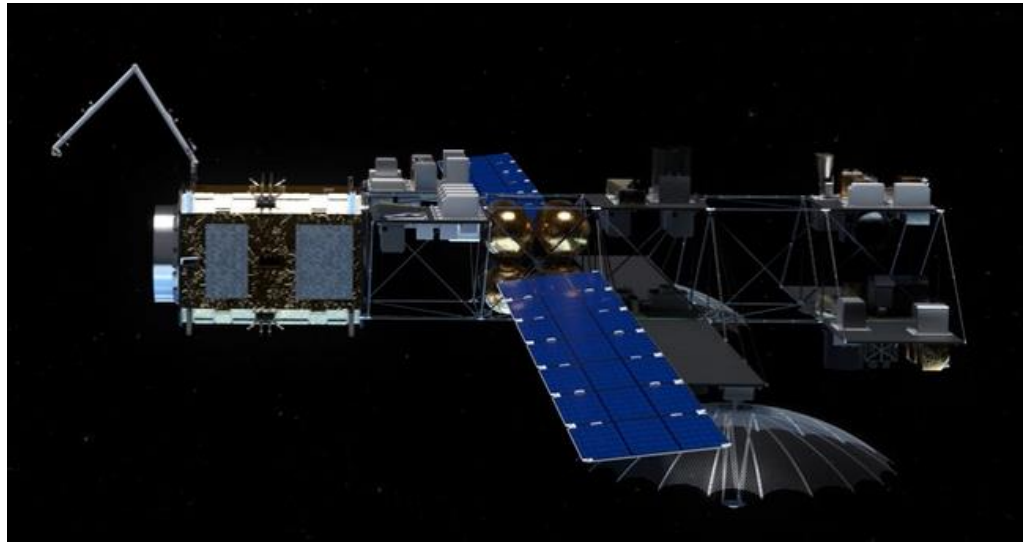
AIAA SciTech Forum, January 6-10, 2020
Orlando, FL

Presentation Overview

- Current Space Paradigm / Single Launch Vehicle
- In-Space Assembly (iSA)
- Space Science and Technology (S&T) Partnership
- Data Collection: Industry Open Forum
- Analysis
- Impact of Analysis
- Follow-on Work/ Closing Remarks

Space Paradigm

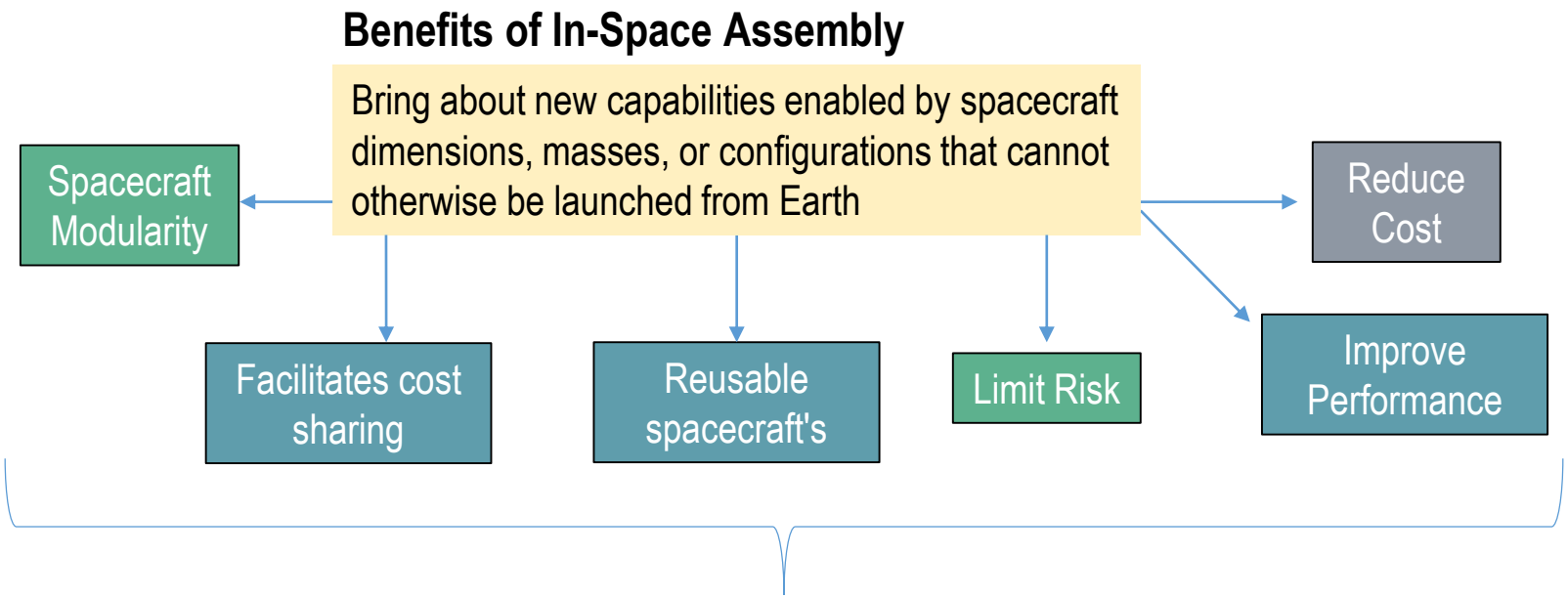
- **Today**: Spacecraft and satellites are currently launched as a single unit to fit within a specific launch vehicle fairing.
- Example of current fairing dimensions.[1]
  - Atlas V:
    - Length: 12 – 26.5 m (39.3 - 87 ft)
    - Diameter: 4 - 5 m (13 - 16.4ft)
  - Antares
    - Length: 9.9 m (32.5 ft)
    - Diameter: 3.9 m (12.8 ft)
- **Problem:** How do we get around the current geometric and mass constraint?



RAMSES concept for a persistent platform
(Credit: NASA)

[1] (2018) *The Annual Compendium of Commercial Space Transportation: 2018*

In-Space Assembly



When mature, in-space assembly, combined with in-space servicing, could produce significant advantages in spacecraft cost, performance, and risk.

In-space assembly (iSA) was the focus of the topic area that NASA, under the direction of the Office of Chief Technologist, coordinated among the S&T principal partners and affiliate partners.

Introduction: Space Science & Technology Partnership

Allow large, persistent space assets to be assembled and routinely upgraded in space

Transform space operations capabilities with economic and performance benefits for both U.S. Government and commercial space endeavors

The Space Science & Technology (S&T) Partnership Forum is a strategic forum established in 2015 to identify synergistic efforts and technologies.

Interagency Science & Technology Partnership Forum

Principal Partners: USAF, NASA, NRO

Affiliate Partners: AFRL, NRL, SMC, DARPA

The S&T Partnership Forum has identified and prioritized pervasive goals (collaboration topic areas) that focus on key game-changing technologies across government space.

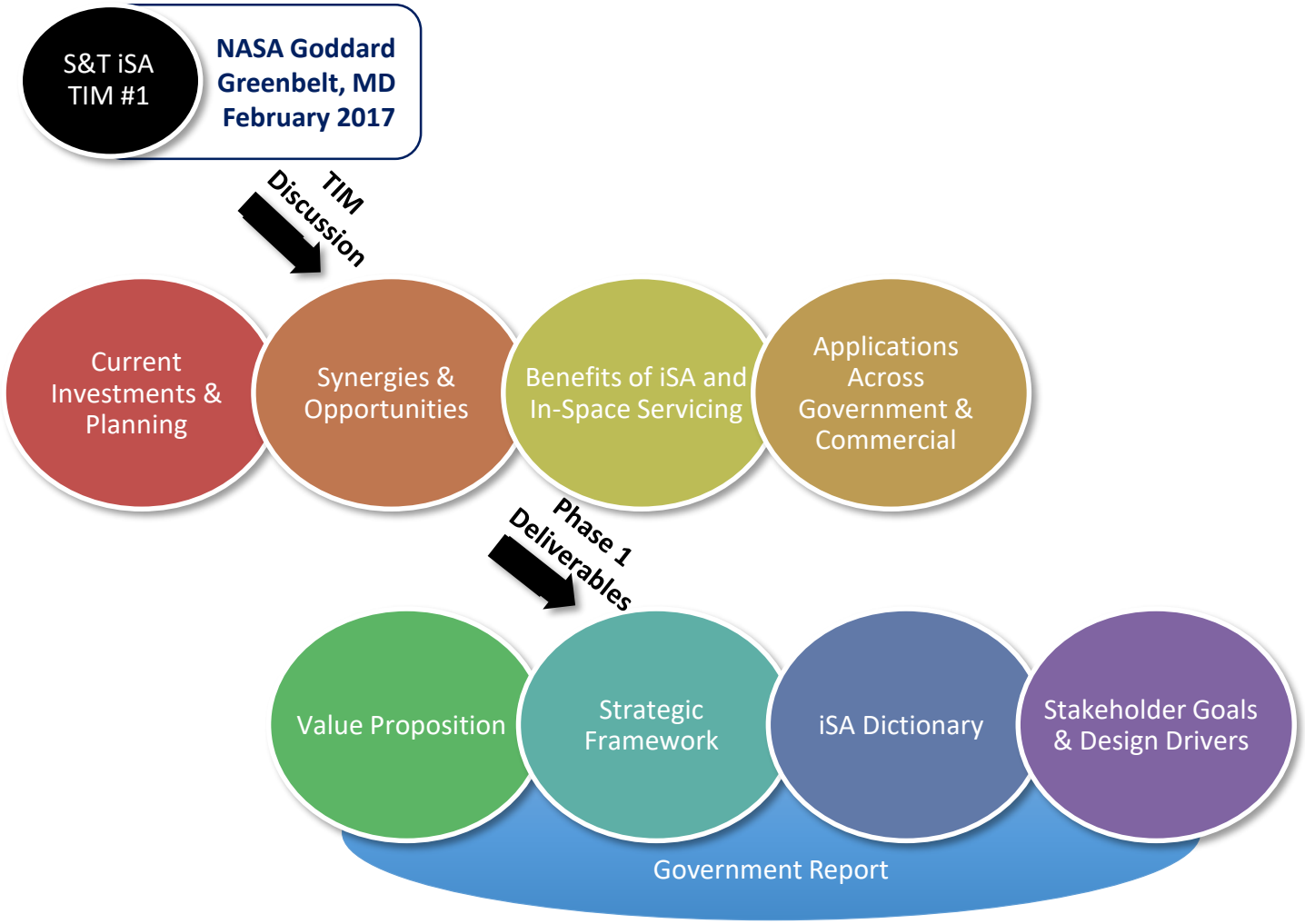
Other Topics
- Small Satellite Technology
- Big Data Analytics
- Cybersecurity

1. Facilitate cross-agency collaboration and strategize on technical solutions to common pervasive needs
2. Maintain awareness of each agency's space S&T investments to reduce duplication and identify areas worthy of collaboration
3. Identify impediments to collaboration and formulate solutions

In-Space Assembly

S&T Strategic Framework for iSA: Phase 1

Objective: Formulate and synergize a strategic framework for iSA for the parenting agencies



1. Conducted TIM, described gov't activities, documented gov't iSA planning

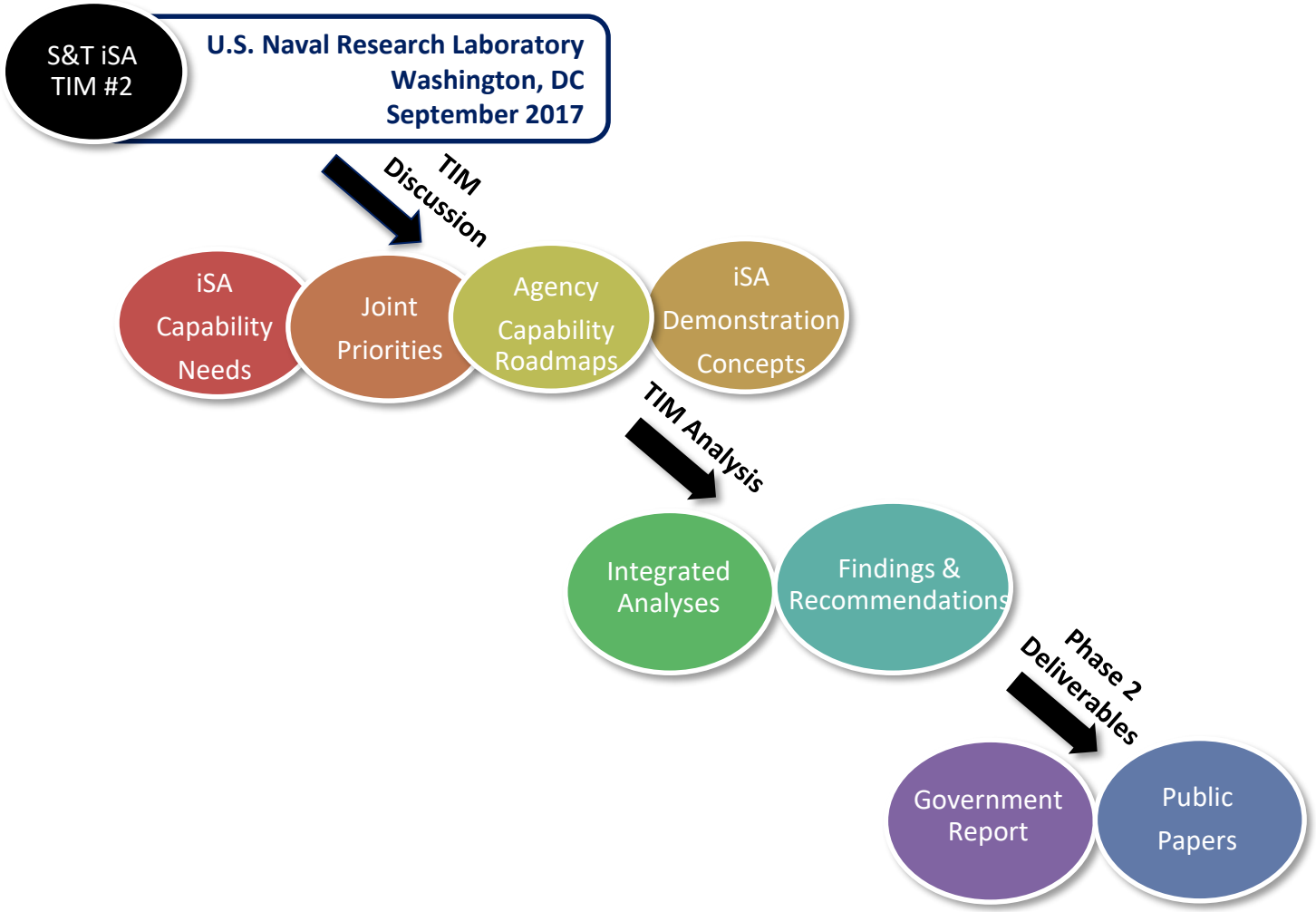
2. Strategized on partnering activities, defined value proposition & strategic plan

3. Categorized capabilities, document benefits, documented potential concepts, identified applicability of commercial sector

4. Integrated TIM data into document, established nomenclature, delivered and communicated document

S&T Strategic Framework for iSA: Phase 2

Objective: Collect and prioritize iSA capability data to discover gaps, synergies, and priorities among the agencies



1. Developed analysis framework, held TIM, collected and prioritized data

2. Defined synergies, gaps, constructed roadmaps, bridged analysis to prioritization

3. Determined and assessed notional demo platforms, developed analytic methodology and FOMs

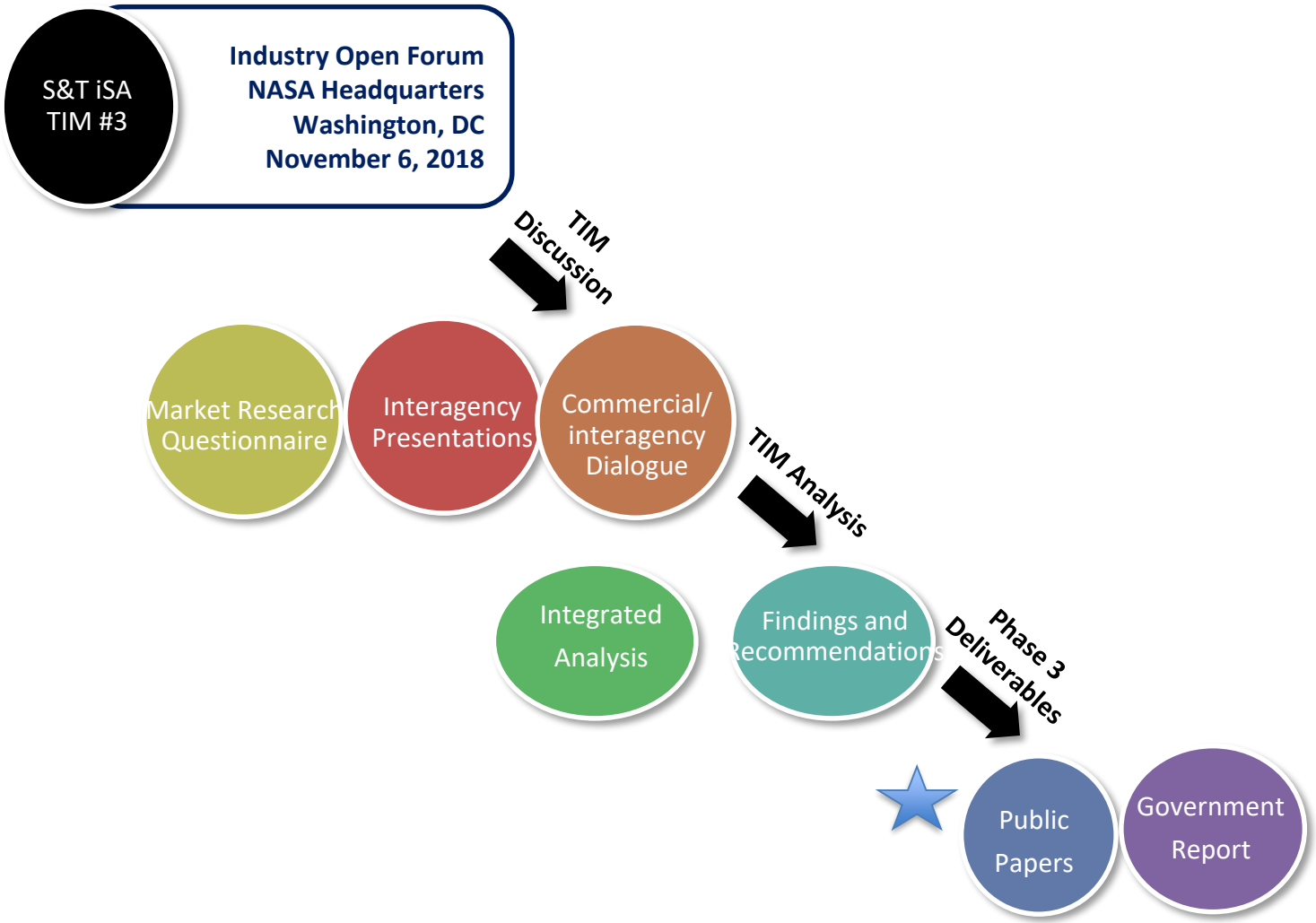
4. Integrated analyses to make gov't partnering recommendations, shared data analysis with principals, **published public papers (2018 AIAA SPACE)**

S&T Phase 2 Results: S&T iSA Capability Areas

1. Deployable modules
2. Structural assembly
3. Connecting utilities
4. Ability to disjoin
5. Sensing, Modeling, Simulation, and Verification
6. Interoperability
7. Automation/Autonomy
8. Precision
9. Adaptive correction
10. Design
11. Tunability
12. Stability
13. Standard interfaces
14. Docking/berthing

S&T Strategic Framework for iSA: Phase 3

Objective: Examine the intersection of government and commercial objectives in iSA



1. Developed market research questionnaire and held TIM/Industry Open Forum to identify American commercial space companies current iSA activities, capabilities, developments, and systems

2. Examined government and commercial activities via aggregated market research questionnaire responses and industry participation/dialogue from the Industry Open Forum

3. Identified and aligned iSA capabilities across the government and industry areas for potential collaboration efforts, capabilities, and space platforms

4. Integrated analyses for gov't partnering recommendations, shared data analysis with principals, **published public papers (2020 AIAA SciTech Forum)**

Commercial Data Sample

- The data was obtained from:
  - Companies who completed the S&T iSA market research questionnaire
  - Companies that participated in the 2018 S&T iSA Industry Open Forum
- These companies were categorized by a market area

Market area of company's iSA technology	Description
Additive Manufacturing	Printing and join materials in space to be assembled together
Interfaces	Connecting space components together
Large Telescope	Building and operating large telescopes in space
Robotics	Perform precise in-space construction/manipulation
Satellite Manufacturing	Produce satellite components in space or from component space resources *(in situ)*
Satellite Servicing	Service other satellites via advanced tools
Satellites & Space Structures	Assemble spacecraft's, satellites, modular platforms
Software, iSA	Operating autonomous systems for path planning/procedures

Commercial Respondents iSA Activity

- Company responses - Market Research Questionnaire
  - Companies were asked to indicate whether they were pursuing, or planning to pursue a given S&T iSA capability and could provide the capability within the next 15 years.
  - The goal of this effort was to understand better what iSA capability areas industry is currently pursuing.

13 most frequent capabilities

Description	Percent of Companies Pursuing
Design for assembly	86%
Deployment Subsystems	79%
Ability to route electrical power and data across assembled joints	79%
Ability to disconnect structural, electrical, and fluid connections without propagating damage to other system components	79%
Modular design	79%
Design for serviceability	79%
Robotic assembly with joining	71%
Ability to reversibly assemble structural, electrical, and fluid connections	71%
Means of verifying the continuity of interface connections / disconnections	71%
Intelligence to make stereotyped decisions correctly without human input	71%
Intelligence for full autonomy	71%
Fail-safe modes of behavior on failure detection	71%
A limited number of standard mechanical, electrical, thermal, and fluid connection approaches with well-characterized properties	71%

iSA Activity Alignment

- The previous tables and charts indicate commercial respondents are actively pursuing the S&T capabilities.
  - This is an early indication of mutual alignment between government need and industry activities

Region	# Capabilities	% Range of Companies Pursuing Capabilities
LOW NEED, LOW INVESTMENT	1	64%
LOW NEED, SOME INVESTMENT	1	64%
GAPS	7	21 – 64 %
POTENTIAL FOR COLLABORATION	17	50 – 71 %
HIGH POTENTIAL FOR COLLABORATION	20	43 – 86 %

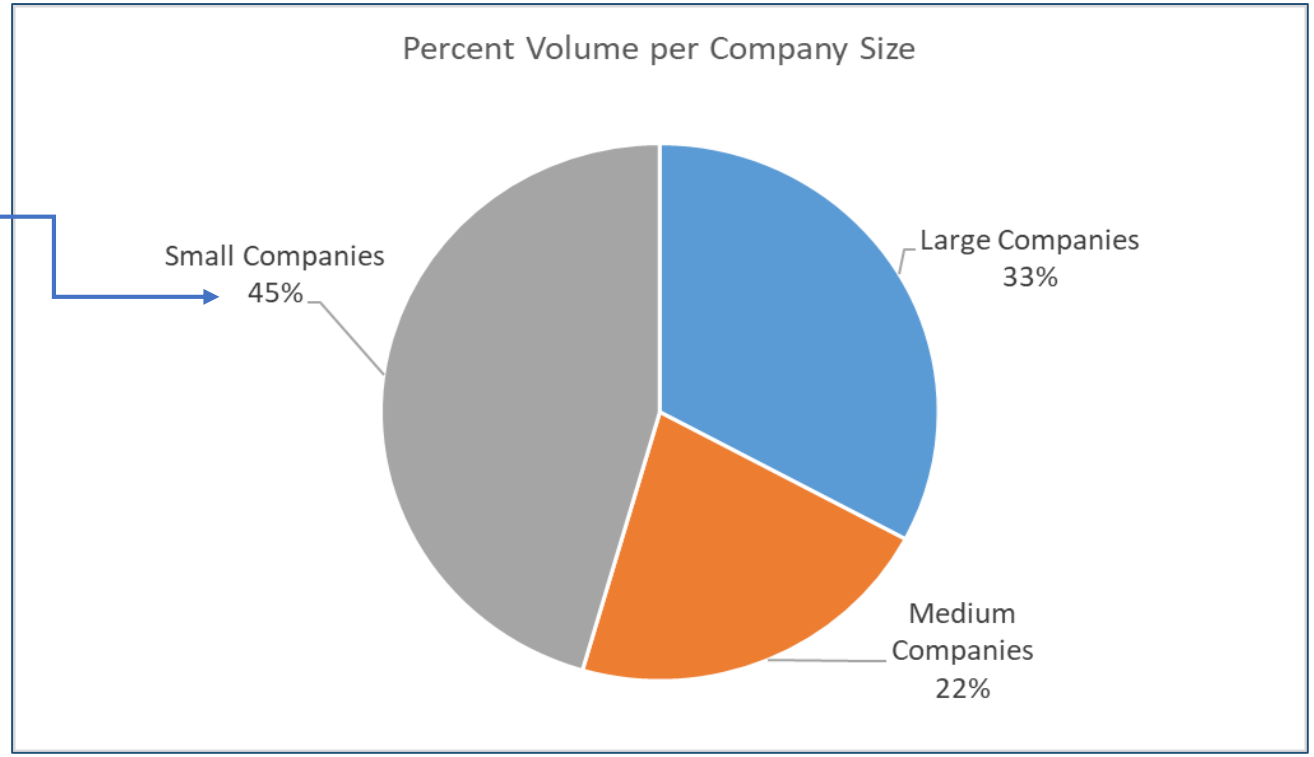
Gov't Need & Investment Levels	Description
Low Need, Low Investment	0 or 1 gov't agency identified capability as enabling or supporting one of its operational missions
Low Need, Some Investment	1 or 2 gov't agencies identified capability as enabling or supporting one of its operational missions
Gaps	0 or 1 gov't agency identified capability as enabling or supporting one of its operational missions *Also very little investment in capability development*
Potential for Collaboration	2+ gov't agencies identified capability as enabling or supporting one of its operational missions
High Potential for Collaboration	All gov't agencies identified capability as enabling or supporting one of its operational missions

Industry Participation Breakdown

- The industry activity was also categorized by company size to better understand how activity differed between smaller, medium, & larger companies.
- The metric used to compare is the **volume of work**

$$Volume\ of\ work = \#\ Capabilities\ pursued \times \#\ Companies\ Pursuing$$

Smaller companies were pursuing, or planning to pursue, almost **half** of the iSA technologies and capabilities.



Company Size Definitions:

- Small = 500 employees or less
- Medium = 501 – 1000 employees
- Large = 1001 employees or more

Industry Respondents' iSA Challenges Definitions:

Lack of Business Case – A reason, or justification, for doing a proposed project, mission, or demonstration for in-Space Assembly (iSA).

Technical Immaturity – Technology that has not been tested or proven to be reliable in a space mission scenario. Technology Readiness level below nine.

Lack of an On - Orbit Demonstration Platform – A platform, in space, which allows commercial, academia, and government agencies to test their technology on a space-platform to enhance pre-mature technologies, and advance the technology readiness level through in-space demonstrations.

Lack of Standards – A global rule or definition approved by an authoritative agency to set a specific benchmark for a given technology or capability.

Lack of Collaboration via Public/Private Partnership (PPP) – The need for a collaboration of some sort, with a public company interested in iSA and government agencies participating in iSA, for the purpose of fulfilling an iSA mission or technology demonstration.

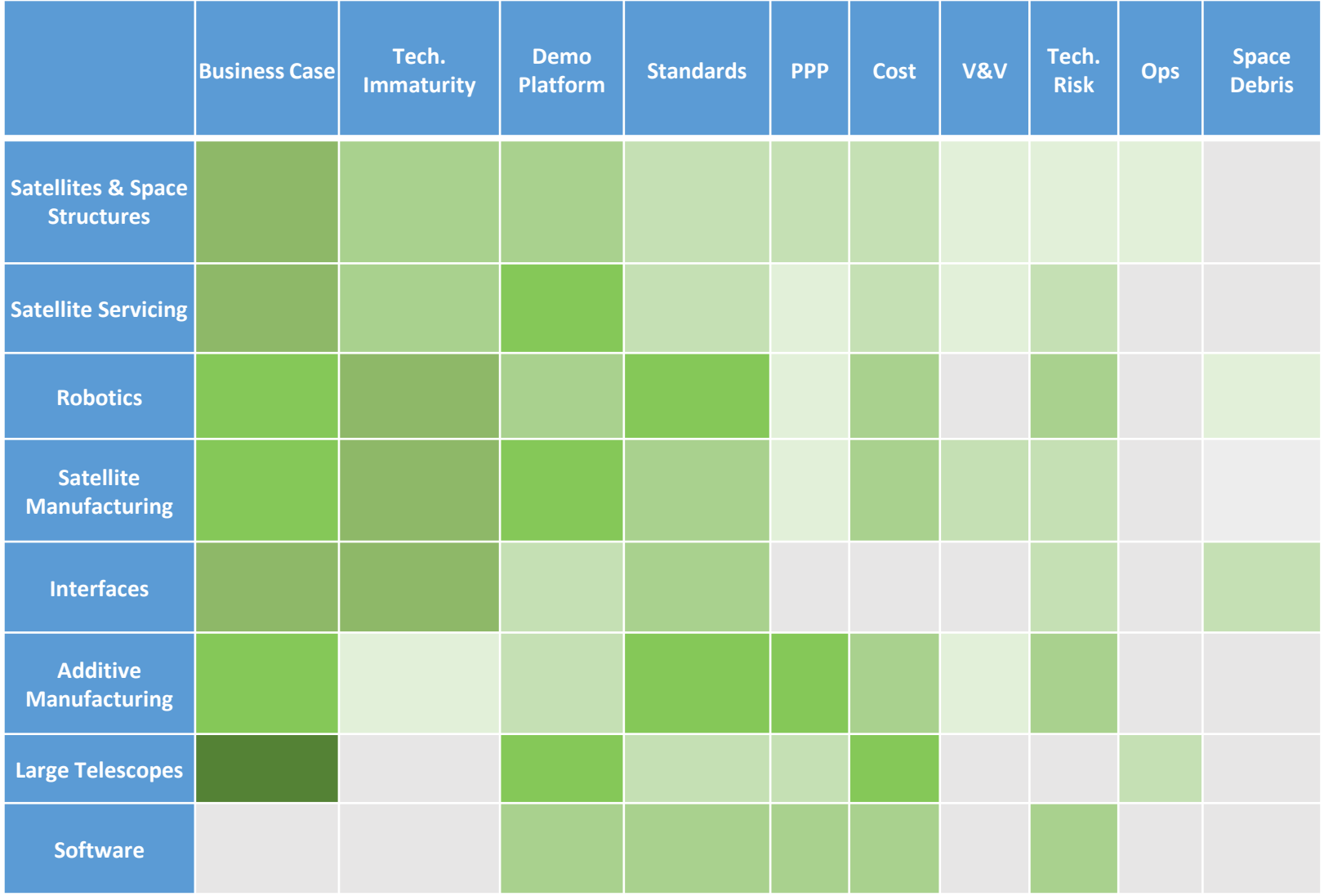
Prohibitive Cost – The difficulty of overcoming some financial barrier; due to either restrictions financially, and/or excessively high launch prices.

Verification & Validation (V&V) – The need to check that a system meets all requirements and specifications in order to fulfill a desired mission.

Technical Risk – A loss arising from the design, engineering, assembly, manufacturing, and/or technology procedures.

Operational (Ops) – An unforeseen hurdle or encounter occurring real-time during a particular mission or demonstration.

Space Debris Mitigation – The task of reducing the natural (meteoroid) and artificial (man-made) particles from low-Earth orbit.



Color Scale Legend

**Note – The varying colors within the table above represent the number of times a company identified a given challenge within a specific market area.*

Commercial Space Companies Challenges & Barriers

- The Facilitation and Analysis Team collected 79 different iSA challenges from the participating commercial companies.

Identified 4 major challenge areas for commercial space companies

1. Technical Immaturity

87% of commercial respondents

2. Lack of iSA Standards

73% of commercial respondents

3. Lack of an On – Orbit Demonstration Platform

67% of commercial respondents

4. Lack of Business Case

67% of commercial respondents

Collaboration Example: Platform Analysis

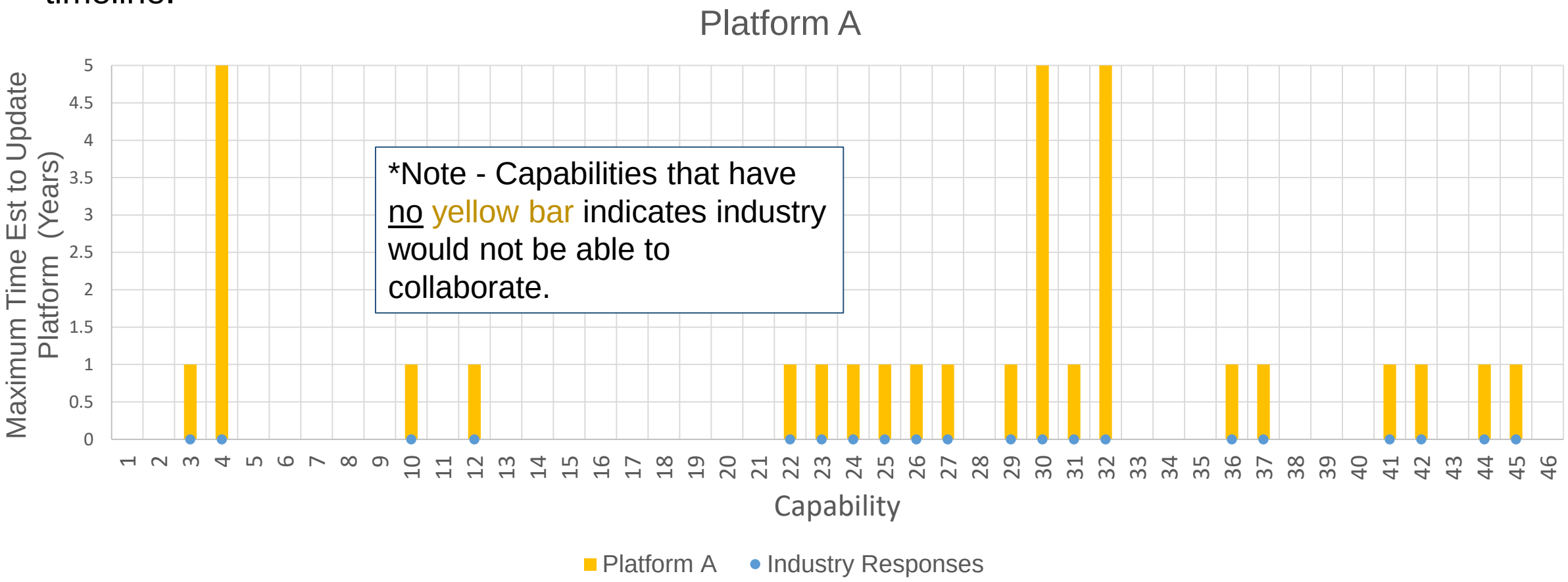
- Government agencies within the S&T partnership have plans to demonstrate in-space assembly on various platforms.
  - *Platforms – Physical structures, in space, with the capabilities to perform in space assembly, servicing, or manufacturing.*

- Government platforms were analyzed to determine if there are synergies between commercial company respondents efforts and government platforms' capability accommodations.
  - *A given platform was assessed on whether it supported, or could support, the 46 S&T iSA capabilities, and if so, how much effort would be required to support or to add a capability.*

- The following chart compares the **maximum estimated time** [for government] to update a **notional government platforms** with a given capability, and the **estimated shortest development time** of a given capability from commercial company respondents.

Collaboration Example: Platform Analysis

- For a given capability, at least **one** company stated it has the capability ready now.
- Industry efforts **could be leveraged** to support government iSA development at a potential faster timeline.



Recommendations

- Assist industry with the development of their in-space technologies and capabilities through an **on - orbit persistent platform**.
  - *53% of commercial companies indicated **they're collaborating** with the **government** for their iSA technology developments and activities.*
- **Strengthen** partner agency relationships to avoid overlapping with iSA technologies and capabilities, as well as establish an iSA architecture moving forward.
  - ***Smaller** companies (500 employees or less) are responsible for **45% of current iSA** activities (**medium** and **large** companies contributed to 55% of current iSA activities).*

Impact of Analysis

- There is a **strong interest** by company respondents to collaborate with government agencies to facilitate iSA developments.
- The overall analysis shows that **all commercial respondents** from the questionnaire are **pursuing** or **planning to pursue** capabilities in all regions of government **iSA capability areas**.
- Collaboration amongst gov’t space agencies and commercial space companies could potentially be a ***critical*** step towards developing a space commodity economy, enhancing space technology and human exploration.

Thank you for your attention!

Special acknowledgements to the government agency participants in the interagency Space S&T Partnerships Forum

National Aeronautics and Space Administration (NASA)

National Reconnaissance Office (NRO)

United States Air Force (USAF)

United States Naval Research Laboratory (NRL)

Defense Advanced Research Projects Agency (DARPA)