Challenges in Space

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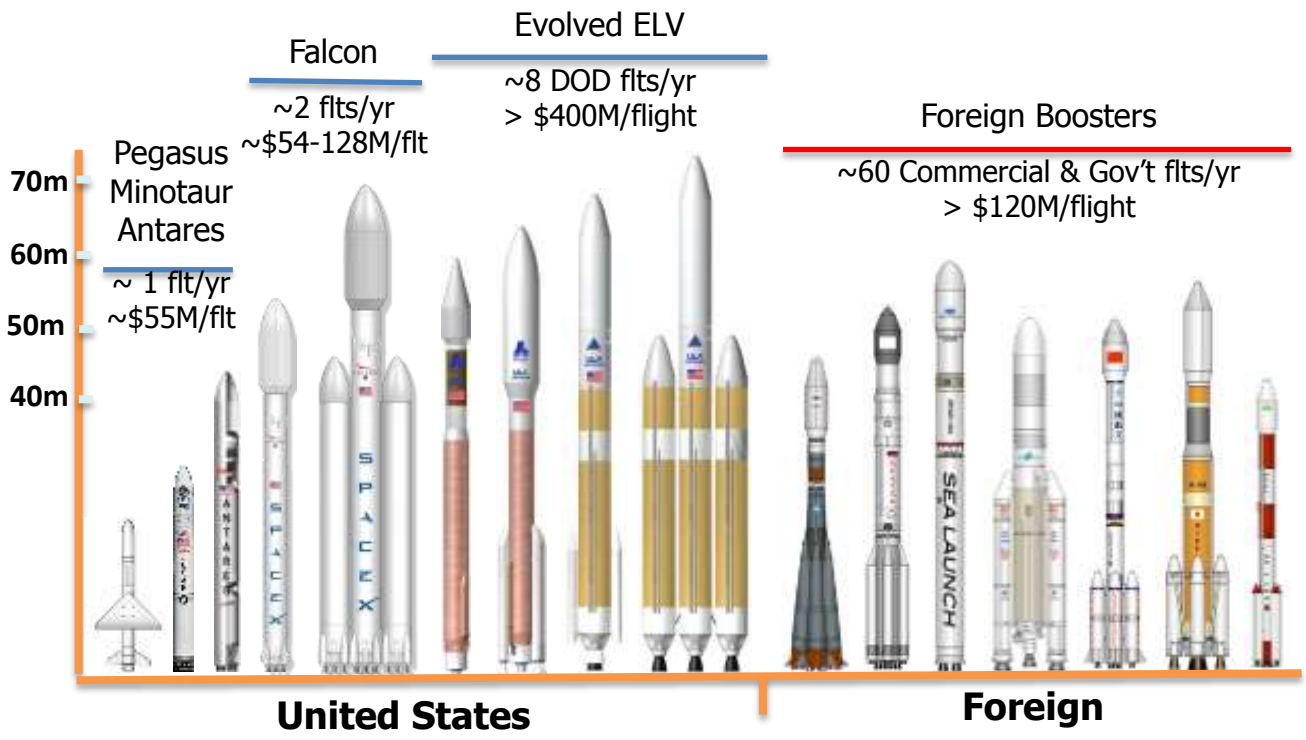
Launch Constraints and Access to Space

Access to Space is Encumbered

Status quo

- DoD payloads launched on Evolved ELV at >$3B/year & growing
- Small payloads launched at $50M+ on few remaining Minotaurs
- No surge capability and long call-up time; up to 2 years wait in queue
- Budgets declining across the department
- Threats to U.S. space and air assets proliferating

Representative Global Launch Capability



Launch is Location-Dependent

- The gateway to space is predominately through two fixed locations
- These locations require repair and refurbishment every time they are used
- Ample precedent exists for making critical security capabilities re-locatable
- Catastrophic weather and geologic events cannot be predicted
- Even common weather events can shut down access to space

- "(We must seek)…reduced vulnerability of relying solely on fixed launch sites and downrange sites by using more space-based capabilities and transportable systems."

  – National Security Space Plan, 3 May 2010

Rocket Technologies Have Stagnated

- Material science has advanced, but new propellants have not been certified
- Continued use of the same available options for the same missions
- Testing is dangerous and expensive

Cost of launch is slowing deployment of new and innovative solutions in space

A New Way to Think about GEO

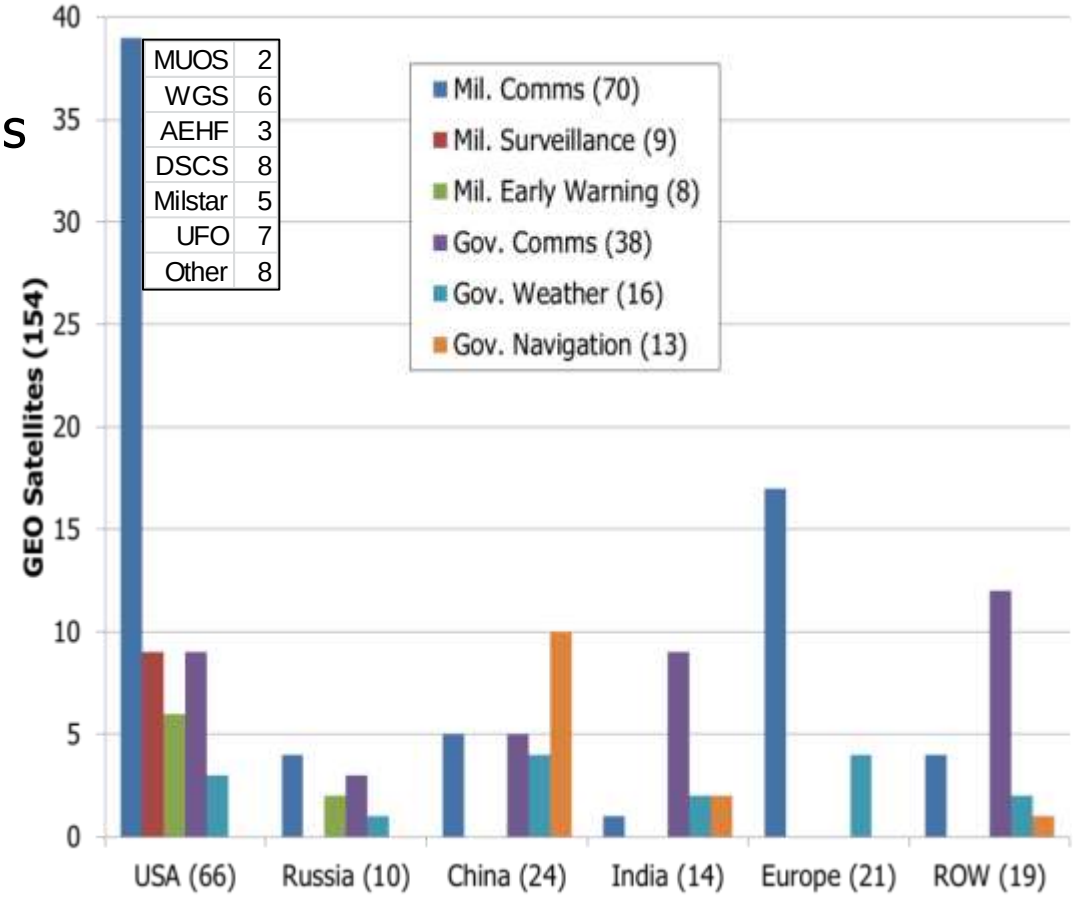
Geostationary Orbit Offers Unique U.S. National Advantages

U.S. Military

- Key strategic assets
  - Nuclear-survivable comms
  - Global comms
  - Missile launch warning
  - Surveillance
- 1-2 launches per year
- Cost ranging from $500M - ~$2.5B per satellite

U.S. Civil

- Weather (NOAA GOES)
- Comms: human spaceflight and science (NASA TDRS)



Of all nations, U.S. national security is by far the most dependent on, and the biggest beneficiary from, GEO systems

GEO is an Austere Outpost Massively Difficult to Access

- Failures are difficult to diagnose and nearly impossible to recover from
- In today's environment, difficult to determine source of anomalies
- Technology "upgrades" are slow and expensive because they are full replacements
- Robust utilization requires infrastructure to supply, sustain and maintain


Artist's concept

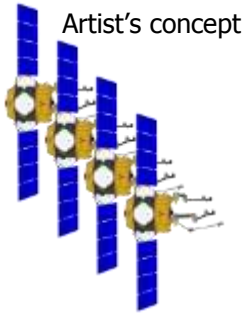

Source: livescience.com


Source: homes-kid.com

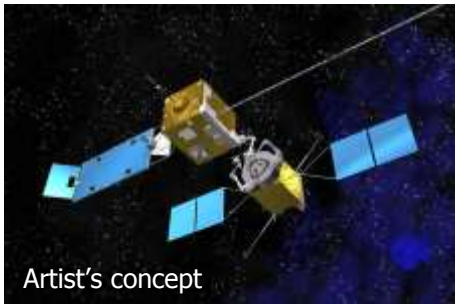
GEO Servicing is the First Step to a Vibrant GEO Logistics Infrastructure

SERVICING

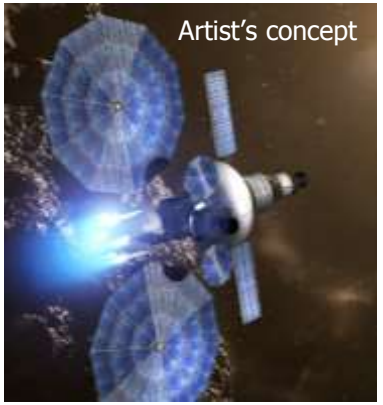
First robotic capability in GEO



Commercial providers expand coverage



Automated, scheduled refueling



LEO-to-GEO space tug

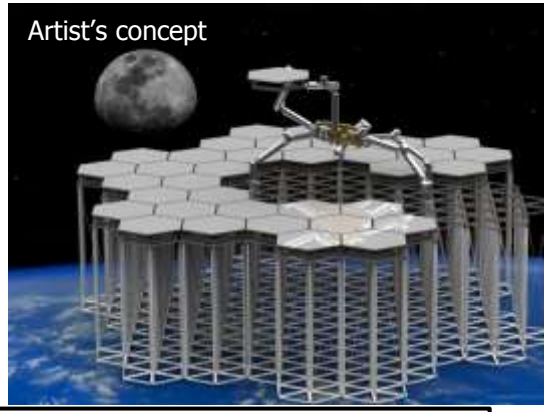
Technology development and investment

NEW ARCHITECTURES

- On-orbit replaceable units
  - Modular spacecraft

- Reduced redundancy
- Lightly fueled at launch
- Assembly experiments

Large apertures, structures and bases

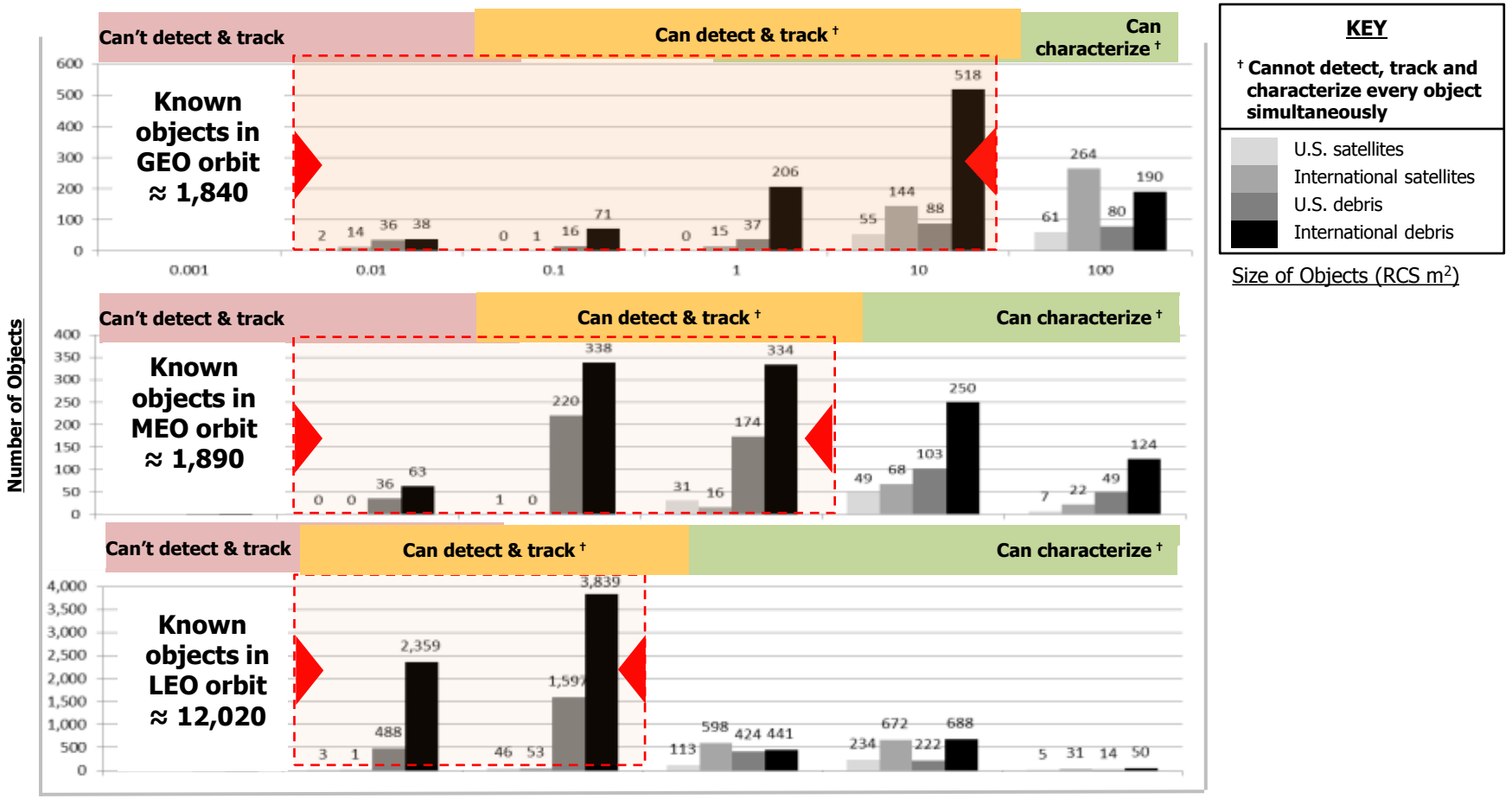


Space robotics = national-level growth potential

Synchronization of Disparate Space Domain Awareness

Space Domain Awareness (SDA) Today

~16,000+ objects in 10^{14} km^3 (240,000 oceans)



SWISSCUBE
RCS: 0.041 m^2

Vanguard 1
RCS: 0.11 m^2

COSMOS 2080
RCS: 1.0 m^2

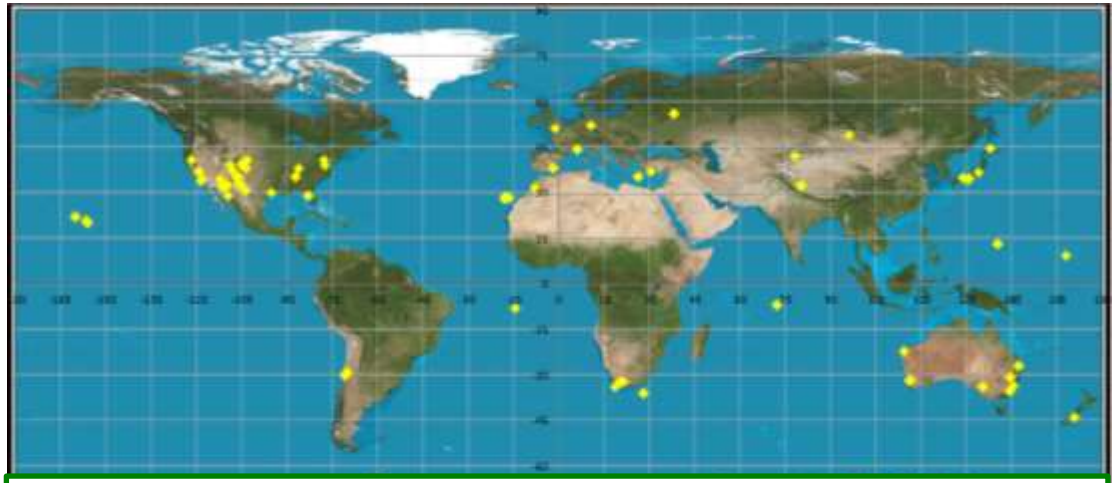
NAVSTAR 64
RCS: 6.3 m^2

ISS
RCS: 227.8 m^2

*data as of 2015

Limitation Gaps in Current Space Domain Awareness

Currently There Are <20 Trusted Usable Sensors for the Space Surveillance Network



However, There Are >200 Commercially Available SSA Sensors

- Limited coverage and ability to share information
- JSpOC currently focuses on collision avoidance and orbital maintenance
- Available sensors are not necessarily trusted or utilized
- Catalog maintenance is daunting at best; the ability to detect, tract and characterize is not adequately monitored

What's Missing? Real-time Awareness

Adequate sensors and data advancements permit information and understanding-centric technology infusion

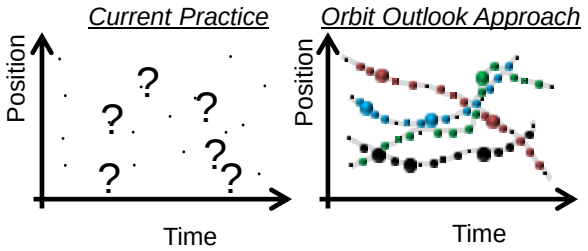
Sensor-centric

- Demonstrating better sensors quality

SST

Data-centric

- Demonstrating non-traditional sensor utility with qualification algorithms



Orbit Outlook

Information-centric

- Producing information from data by application of analysis tools

Decision Tools

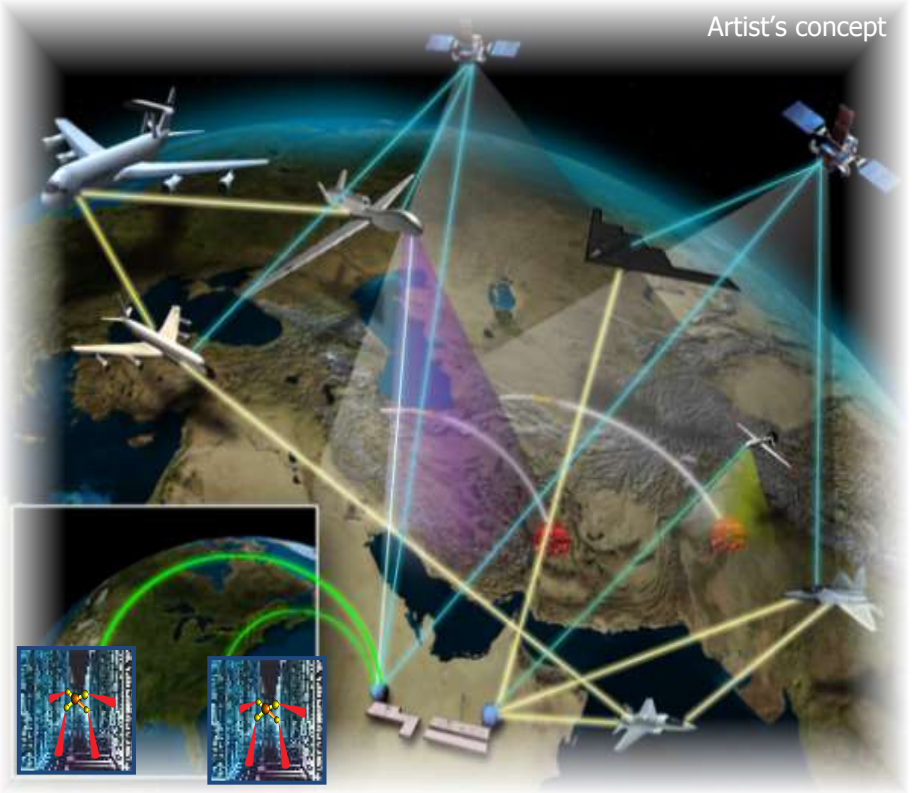
Understanding- and Action-centric

- Apply comprehension techniques to give information utility

Hallmark

Synchronized Operations Could Lead to Real-Time Awareness

- Coordinate and synchronize assets from across air, space, and cyber domains to commander's intent within the JSpOC
- Common plan representation – single instance of the battle plan representing all resources necessary to achieve command direction
- Mixed initiative/advisable planning and scheduling algorithms
- Machine-machine synchronization – operator workflow assistance for course of action planning and execution



Synchronized resources, view and planning

Creating the Future

DARPA Vision for Robust Space

Launch:

- Flexible, affordable access to include augmentation and reconstitution
  - Aircraft-like space access to lower cost and increase capabilities
  - New advances in propellants and rocket design

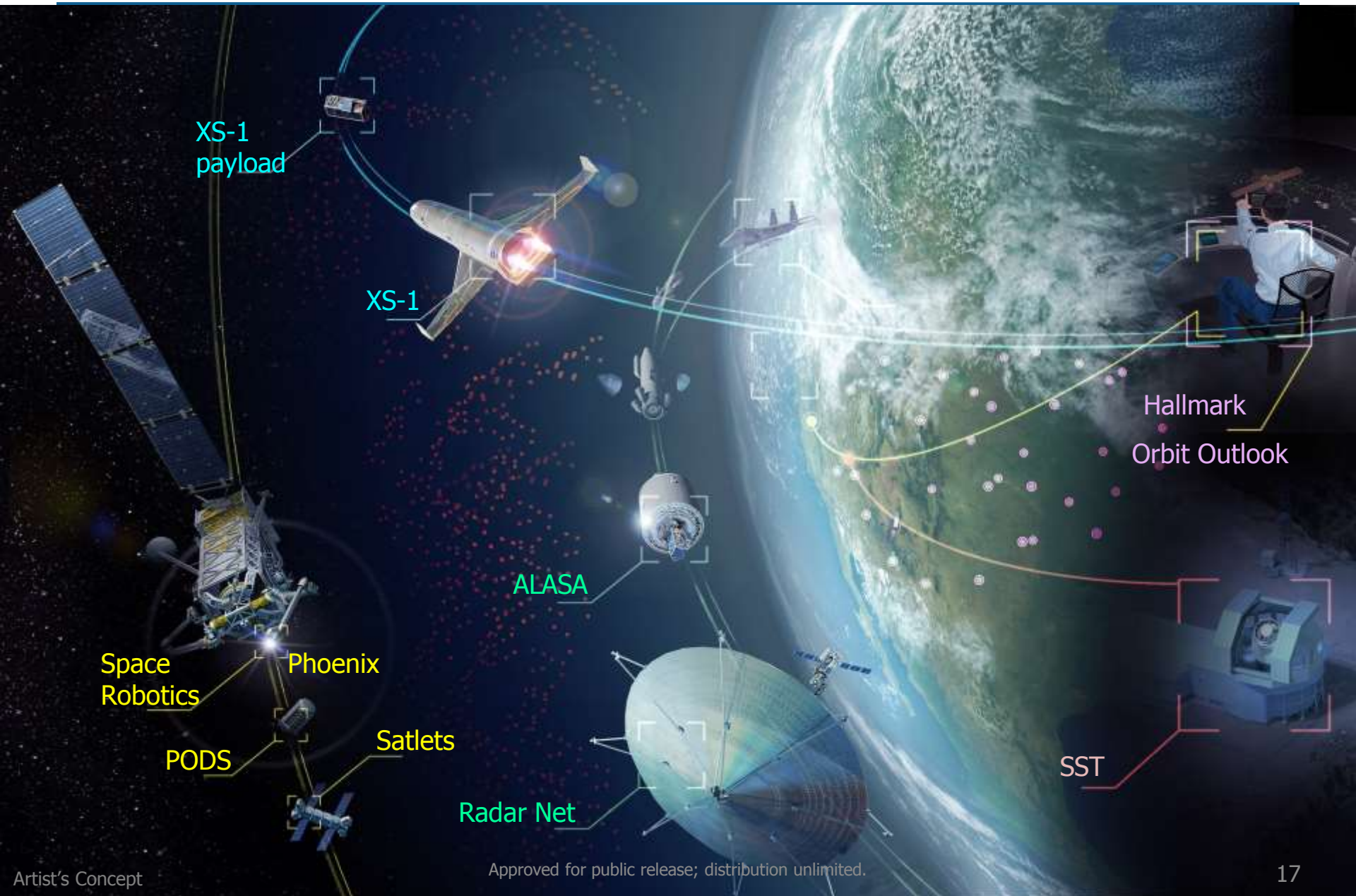
Satellite:

- Changing the paradigm of satellite operations
  - Rapid small satellite constellation capability
  - GEO space robotics
    - Repair, assembly to create new architectures such as propellant depots

Space Domain Awareness (SDA):

- Real-time space domain awareness
  - Real-time detection, tracking, and attribution versus catalog maintenance and days to weeks of forensics
  - Enhance the safety of space operations

Tactical Technology Office Space Portfolio



Artist's Concept

Future Technologies for Increased Capabilities

Future critical investments in cross-domain programs could enable breakthrough technologies to be leveraged in space capabilities, including:

- Novel rocket propulsion – new propellants, new manufacturing, new approaches
- Robotic servicing on-orbit
- International partnerships and data sharing
- Real-time knowledge for space based logistics
- On-orbit assembly

DARPA seeks to fuel and leverage commercial capabilities, and partner with other agencies to augment national and economic security

www.darpa.mil