# Aerospace Technology Gaps and the U.S. Space Force

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# Agenda

*Executive Summary*

*Research Objectives/Methodology*

*USSF Mission/Goals*

*In-Space Propulsion*

*Satellite Communications*

*Conclusion/Recommendations*

# Executive Summary

- In this presentation, we will be analyzing the needs for the future of the U.S. Space Force.
  - how the aerospace industry can develop to fulfill those needs
- We have developed a methodology that initially identified the present and future technology gaps for the Space Force.
  - After recognizing gaps in current technology, our motivation was to find how the aerospace industry is planning to advance
  - Our research encompassed two specific aerospace technologies that are vital for the Space Force

# Research Objectives/Methodology

# Approach and Outcomes

- Identify the strategic objectives of the USSF
  - From Space Force Documentation
- Create a methodology to best determine technology gaps
  - Critical evaluation of available/conceptual technology in a chosen discipline
  - Tested on the following fields:
    - In-Space Propulsion
    - Satellite Communications
- Provide USSF with recommendations

# Methodology

1. Derive USSF Objectives
   - From global trends & USSF documentation
2. Create Hypothesized Mission Profiles
   - Thought exercise to help relate USSF objectives to current technology
3. Infer Technology Needs
4. Research and Analyze Current/Emerging Technology
5. Synthesize the individual capability/need mismatches between steps (3) and (4) into technology gaps

# USSF Missions/Goals

# Global Trends

- Post Cold War: international collaboration in the space domain (ex. ISS)
  - This period appears to be ending
  - Trending toward factionalism
- Russian government still has strong presence in space
- China’s influence is spreading across Asia
  - Rapid development of in-space capabilities
- Potential Chinese-Russian cooperation
- Competition between US, Russia, and China on in-space activities is likely.

# Space Force Objectives*

- Space Superiority
- Space Domain Awareness
- Space Support to Operations
- Space Mobility and Logistics
- Information Mobility

*Document: Comprehensive Plan for the Organizational Structure of the U.S. Space Force

# Hypothesized Mission Profiles

- Protect USSF space assets from hostile threats
  - Kinetic, Laser, Electronic, Cyber Warfare
  - May require rapid response
- Initiating in space offensive maneuvers
  - Blind, disable, or even destroy a target spacecraft
- Planetary and non-planetary surveillance
- Transportation of crews and equipment to, from, and across cislunar space
  - Generally requires larger spacecraft
- Defend commercial/private spacecraft
  - Preserve freedom of action/ensure in-space safety

# In-Space Propulsion

# General Requirements

**1. Impulsive Maneuvers**

- Required thrust dependant on a spacecraft's mass
- Essential for offensive/defensive maneuvers, transportation

**2. Attitude Controls/Orbital Maintenance**

- Attitude control important to complete in-space missions
  - Note: Attitude Control can be done with reaction wheels
- Orbital maintenance required to correct prevent orbital drift

**3. Longevity**

- Spacecraft's lifespan exceed its mission length (10+ years)
- Fuel requirements often a limiting factor

**4. Deorbiting Ability**

- Necessary to prevent accumulation of space debris

# Technology

**Chemical Propulsion**

- Typically used on medium/large spacecraft
  - Well-understood, flight-demonstrated
- Capable of high thrust, but comparatively low $I_{sp}$

**Electric Propulsion**

- Often used for small spacecraft and deep-space missions
  - Some methods are well understood (HETs)
  - Currently lots of innovation in this field
- High $I_{sp}$, but intense power requirements limit thrust

**Nuclear Propulsion**

- Use of fission/radioisotopes to (in)directly provide thrust
  - Early stages of development
- Nuclear Thermal: high $I_{sp}$ and thrust for in-space applications
- Nuclear Electric: used in conjunction with electric propulsion

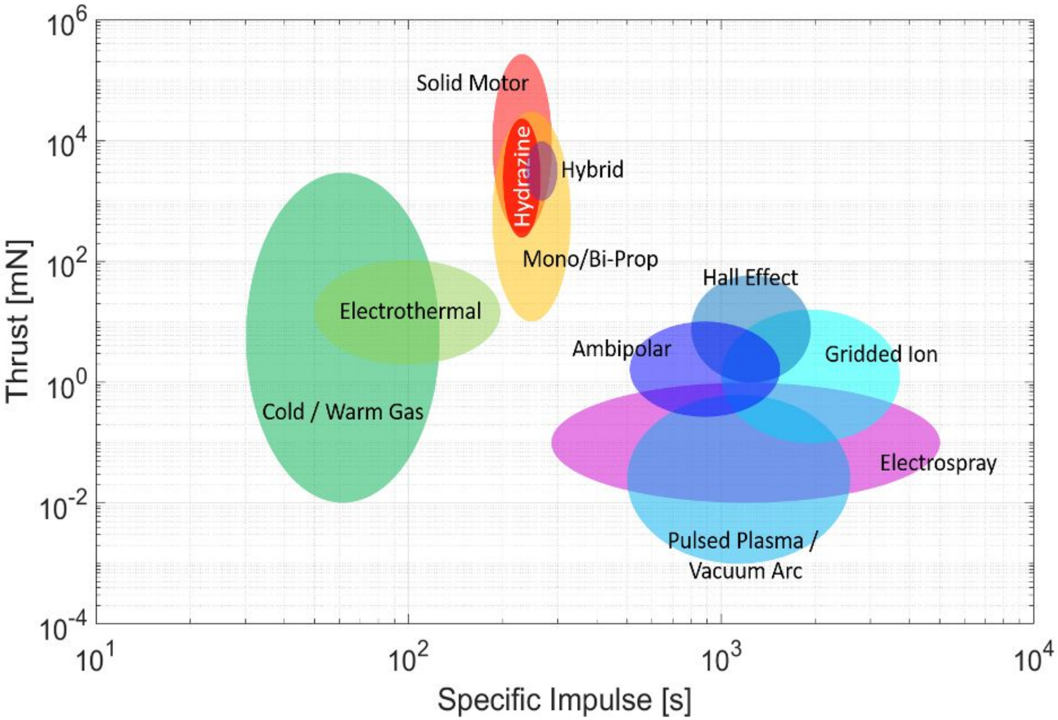
# Thrust and Specific Impulse

**Thrust**

- Higher thrust leads to faster maneuvering
- Larger mass -> lower acceleration

**Specific Impulse ($I_{SP}$)**

- Increases thrust by increasing exhaust velocity
- Higher $I_{SP}$ leads to less fuel consumption



# Fulfillment of Individual Needs

**1. Impulsive Maneuvers (Met)**

- Variety of chemical propulsion technologies (bipropellants) meet this need
- Small spacecraft can use electric propulsion
- Nuclear Thermal a great option with development, high $I_{sp}$

**2. Attitude Control/Orbital Maintenance (Met)**

- Monopropellants, cold gas, electric propulsion are effective options

**3. Longevity (Met)**

- Reducing fuel consumption (increasing $I_{sp}$) is key
  - High $I_{sp}$ electric systems such as HETs and Gridded Ion are great solutions
- Nuclear Propulsion also offers impressive $I_{sp}$

**4. Deorbiting Ability (Met)**

- Aerodynamic Drag, Electrodynamic tethers can be used in cislunar space
  - Uncontrolled Solution
- Electric propulsion systems also an excellent, controllable option

# Synthesis of Needs

**1. Impulsive Maneuvers & Longevity (Not Met)**

- Electric Propulsion meets both needs for small spacecraft
- Larger spacecraft generally require chemical propulsion
  - Requires in-space refueling
- Nuclear Thermal is a potential future solution

**2. Attitude Controls/Orbital Maintenance & Longevity (Met)**

- Electric propulsion fulfills this need; chemical propulsion does not
  - Low thrust requirement means these systems can be very efficient

**Takeaway:** the lack of high thrust, high $I_{sp}$ solutions is the most significant propulsion technology gap the USSF is facing.

# Satellite Communications

# General Requirements

**1. Security and Confidentiality**

- Prevent access to information

**2. Information Mobility**

- Reliability of transmissions
- Rapid timing of transmissions
- Ability to respond to threats swiftly and seamlessly

**3. Resiliency**

- Maintain communications in all operating environments
- Diversified and proliferated satellite communication capabilities

# Technology

**RF Communication**

- Conventional method of SATCOM
- Responsible for majority of communications today

**Optical Communication**

- Newer, promising method of SATCOM

**Data Processing**

- Set of technologies responsible for sending, receiving, and interpreting communications

# Fulfillment of Individual Needs

**1. Security and Confidentiality (Met)**

- Current technology like Protected Tactical Waveform offers secure communication capabilities
- Could be improved with innovation in quantum cryptography

**2. Information Mobility (Not Met)**

- An ever increasing demand for bandwidth requires improvements upon conventional RF technology to combat spectrum congestion
- With further development, optical communication and the use of higher frequency bands could meet requirement

**3. Resiliency (Not Met)**

- MILSATCOM currently relies on a small number of large multipurpose satellites
- Disaggregation could meet requirement by providing redundancy and target diversity

# Synthesis of Needs

**1. Security and Confidentiality/Information Mobility (Not Met)**

- Protected communication is currently very limited in capacity
- Optical communications are more secure than RF communications and more readily deployed

**Takeaway:** The lack of widespread protected communications is a significant problem facing the USSF

# Conclusion/Recommendations

# Summary: Propulsion

**Conclusions**

- Modern technology adequate to fulfill most USSF objectives
- Large spacecraft limited by fuel requirements

**Recommendations**

- Focus on small spacecraft development in the short term
  - Can meet our longevity requirement via electric propulsion
- Invest in Nuclear Thermal Propulsion research
  - Eventually large spacecraft will be necessary
  - Even with nuclear propulsion, in-space refueling will eventually be necessary

# Summary: Communications

## Conclusions

- RF spectrum congestion and increasing bandwidth demands pose big problem
- Advancements in optical communications or higher frequency bands are necessary to meet requirements
- Older space systems that prioritize size and capability are high-value, easily identifiable targets

## Recommendations

- Focus attention on development of antenna technology to cover new frequency bands (including optical frequencies)
  - Cost, power consumption, miniaturization, efficiency
  - Promising techs include metamaterial, 3D-printed, and fractal antennas
- Implement disaggregation sooner rather than later
  - Redundancy, target diversity

# Learning Outcomes

**During Research:**

- More involved in current events regarding space policy
- Understanding the urgency of space security
- Assessing applications of aerospace technologies to Space Force needs
- Forming hypotheses and utilizing documentation to develop an informed viewpoint

**Follow-Up:**

- Continue to stay updated with current events
- Apply this research method to other technologies
- Applying knowledge to our aerospace careers
- Using what we learned as motivation for our studies
- Informing others and seeking knowledge from professionals

# Thank you!

Questions, comments, concerns?

# Discussion

We are writing a research paper which covers these points in more detail.

- What technology is the aerospace industry lacking on the most? What developments need to be made with that technology?
- What research methods would help our analysis?
- Are there any resources you would recommend for learning more about the needs of the Space Force?
- What are some emerging threats that the aerospace industry has not begun to address yet?