Space Propulsion

John Henderson
Space Systems Company’s (SSC) Portfolio

SSC’s Space Portfolio Integrates a Vast Array of Technologies
Types of Spacecraft Propulsion

- Rocket Propulsion
  - Chemical Propellant
    - Solid
      - Monopropellants
    - Liquid
      - Monopropellants
      - Bipropellants
    - Cold Gas (compressed gas)
  - Added Energy Source
    - Electrical Energy
    - Nuclear Energy
    - Solar Energy
  - Augmented Chemical Propellant
    - Monopropellant with electrical Augmentation
      - Electrothermal Hydrazine Thrusters
      - Arcjets

- Non-Rocket Propulsion
  - Cold Gas
  - Electrical Energy
  - Nuclear Energy
  - Solar Energy

- Augmented Chemical Propellant
  - Monopropellant with electrical Augmentation
    - Electrothermal Hydrazine Thrusters
    - Arcjets
Types of Spacecraft Propulsion

- **Rocket Propulsion**
  - Chemical Propellant
    - Solid
    - Liquid
      - Monopropellants
      - Bipropellants
        - Storable
        - Cryogenic
        - Hygrolic
        - Non-Hygrolic
      - Cold Gas (compressed gas)
    - Electrical Energy
  - Added Energy Source
    - Nuclear Energy
    - Solar Energy
    - Augmented Chemical Propellant
      - Monopropellant with electrical Augmentation
      - Electrothermal Hydrazine Thrusters
      - Arcjets

- **Non-Rocket Propulsion**
  - Solar Sails
  - Tethers

Photo/artwork Credit - NASA
Types of Spacecraft Propulsion

- **Rocket Propulsion**
  - **Chemical Propellant**
    - Solid
    - Liquid
      - Monopropellants
        - Storable
        - Hypergolic
      - Bipropellants
        - Storable
        - Cryogenic
  - **Added Energy Source**
    - Cold Gas (compressed gas)
    - Electrical Energy
    - Nuclear Energy
    - Solar Energy
  - **Augmented Chemical Propellant**
    - Monopropellant with electrical Augmentation
      - Electrothermal Hydrazine Thrusters
    - Arcjets

Photo Credit - NASA
Types of Spacecraft Propulsion

Spacecraft Propulsion

Rocket Propulsion

Added Energy Source

- Cold Gas (compressed gas)
- Electrical Energy
- Nuclear Energy
- Solar Energy

Augmented Chemical Propellant

- Monopropellant with electrical augmentation

- Electrothermal Hydrazine Thrusters
- Arcjets

Additional Energy Source

- Electrical Energy
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Augmented Chemical Propellant

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Types of Spacecraft Propulsion

Spacecraft Propulsion

Rocket Propulsion

Added Energy Source

- Cold Gas (compressed gas)
- Electrical Energy
- Nuclear Energy
- Solar Energy

Cold Gas Thruster System

Photo Credit - NASA
Types of Spacecraft Propulsion

- **Rocket Propulsion**
  - Added Energy Source
    - Electrical Energy
    - Nuclear Energy
    - Solar Energy

- **Non-Rocket Propulsion**
  - Nuclear Concept
  - Solar Thermal Concept

Artwork Credit - NASA
Types of Spacecraft Propulsion

- Rocket Propulsion
  - Added Energy Source
    - Electrical Energy
  - Chemical Propellant
    - Solid
    - Liquid
    - Monopropellants
    - Bipropellants
    - Storable
    - Hypergolic
    - Non-Hypergolic
    - Cryogenic
- Added Energy Source
  - Cold Gas (compressed gas)
  - Electrical Energy
  - Nuclear Energy
  - Solar Energy
- Augmented Chemical Propellant
  - Monopropellant with electrical augmentation
  - Electrothermal
- Non-Rocket Propulsion
  - Ion Thruster
  - Hall Effect Thruster

Photo Credit - NASA
Electric Propulsion Missions

✓ Communication Platform Stationkeeping
✓ GEO Transfer Orbit Completion
✓ Exploration of the Asteroids

• All Electric Propulsion Platforms
• Electric Propulsion Cargo Vehicles
• Exploration of the Solar System

Limitations in thrust has discouraged the more widespread use of these systems
Critical Technologies for EP

• High Power Generation
• High Power Conditioning and Control
• Thermal Control Technologies
• High Thruster/Specific Impulse Engines
• High Temperature Materials
• Engine Plume Control Technologies
Model Based
System Design Integration

Brett Tobey
One of SSC’s Key Engineering Challenges: Addressing Complexity and Delivering Affordability

Technology Advances have blurred the line between hardware and software through the use of devices like FPGAs.

While complexity is on the rise, our customers are demanding more affordable products and solutions in less time.
Model Based Enterprise Strategic Initiative:

Today: Document driven, loosely connected modeling and simulation efforts, labor intensive integration

Future: Highly integrated data sets, tightly coupled modeling and simulation efforts, efficient system integration
Model Based Enterprise
Spiral Development Strategy:

Elements:
MBE Capabilities to Address Strategic Enterprise Wide Objectives

Implementation:
Ongoing MBE Projects Focused on Program Needs

Infrastructure:
Phased Capability Insertion of MBE Expertise, Processes, Tools, and Training
SysML: Enables a New Level of Mission Engineering and Design Integration

System Architecture Model (SAM):

- A well defined SAM is the loom that weaves the many threads of digital information together.

- The SAM helps link requirements to logical and behavioral design.

- Requirements can be fed into increasingly detailed levels of domain specific modeling.

- By viewing the SAM as the hub of the digital tapestry, an integration pattern emerges enabling cross-domain connectivity with a minimal set of required integrations.
SSC’s Mechanical CAD Future, 3D Model as Digital Record-of-Authority

Fully Dimensioned Drawing
Data Set Rating (DSR) 1

Drawings are sole source for design data

Reduced Dimension Drawing Data Set

Models are source for geometry data, drawings for all else

Model-Only Data Set
DSR 6

Models are sole source for design data

Model Centric Mechanical Engineering
SSC’s Future in Virtual Manufacturing, Virtual Creation before Physical Creation

Visualization enables effective and early Engineering, Manufacturing, and Production collaboration.
Virtual Systems Integration & Test, Drive Out Engineering Errors Early

Early Problems Found Late

Design → Physical Build → Physical Test/V&V → Delivery

Physical Re-work

Low Cost of Re-work $$$ High

Early Problems Found Late

Design → Virtual Integration → Virtual Test/V&V → Physical Build → Physical Test/V&V → Delivery

MBE Virtual Re-work

Low Cost of Re-work $ High
Model Based Enterprise
Strategic Imperatives:

1) Apply Across Corporation

2) Engage With Customer

3) Systematically Deploy Capabilities

**MBE V₁**
2007
Auto Coding & Model Sharing

**MBE V₂**
2010
Virtual Manufacturing

**MBE V₃**
2012
Digital Tool Integration

**MBE V₄**
2013
Design Integration

**MBE V₅**
2014
Enterprise Collaboration

**MBE V₆**
2015
Architecture Commonality