International Council on Systems Engineering
A better world through a systems approach

Intelligent Exploration

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Hello.

Kathleen Ticer

Requirements Manager, USAF
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Kathleen is a seasoned communications, surveillance, and IT professional with 16 years of decorated service in the U.S. Air Force. She has performed flight communications operations senior government leaders and applied systems engineering to meet the requirements and acquisitions of executive airlift missions.

David Gross, PhD

Teaching Faculty; Systems Engineering Program- Florida State University (FSU)

David C. Gross is an expert in model-based systems engineering, digital engineering, and simulation, with leadership experience at Boeing and Lockheed Martin. He has driven innovations valued over $1 billion and now serves as a faculty member at Florida State University.

Calen Sims

Systems Engineer, Lockheed Martin
Graduate Mentor, Florida State University

Calen is a Systems Engineer at Lockheed Martin specializing in HWIL testing, integration, and Model-Based Systems Engineering. With a background in embedded software and DevSecOps, he previously served as a Computer Engineer with the U.S. Navy and now mentors engineering students at Florida State University Panama City.

Today's Agenda

Outlining a Systems Engineering Approach to Integrate AI, Robotics, and Optical Communications to Enable Habitability Assessments in Deep Space

- Introduction
- AI in Space Exploration
- Optical Communications
- Robotics Platforms
- Systems Engineering Methodology
- Feasibility Analysis
- Conclusions

Introduction

- Exploring Extraterrestrial Environments
- Research Focus
- Research Significance
- Key System Needs (Visualized in Figure 1)

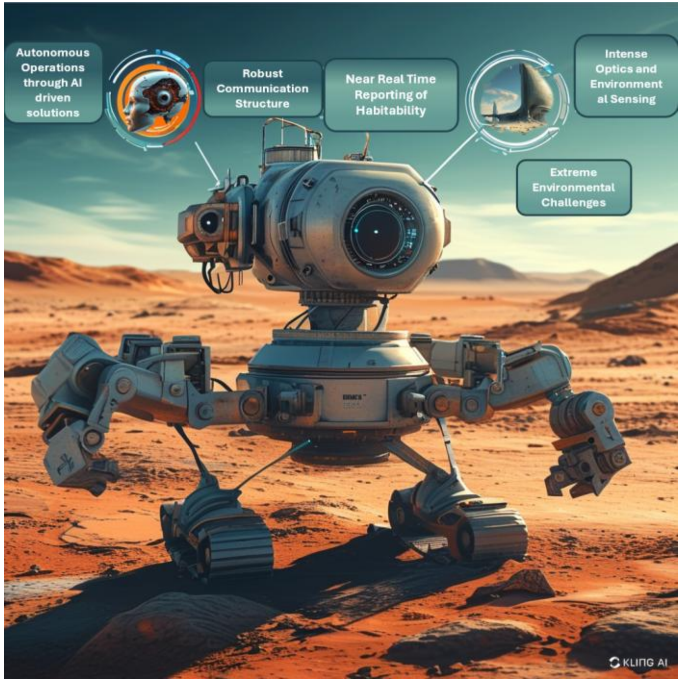
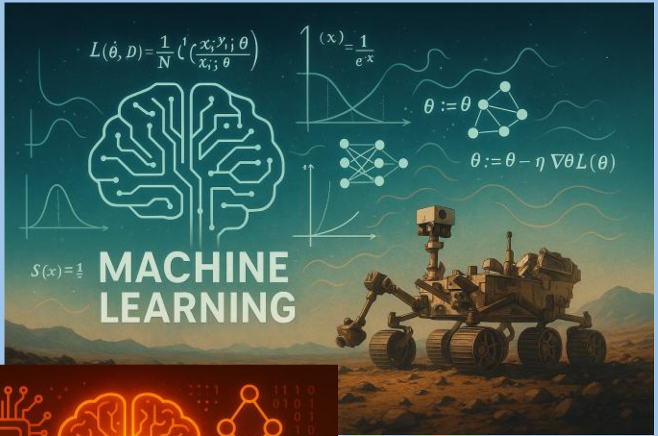
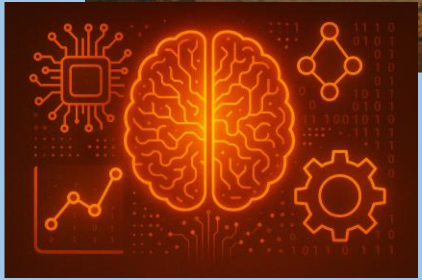


Figure 1.Intelligent Explorations Challenges Visual (Kling, n.d.)

AI in Space Exploration





AI Generated Visual Representations (GPT4.0, 2025)

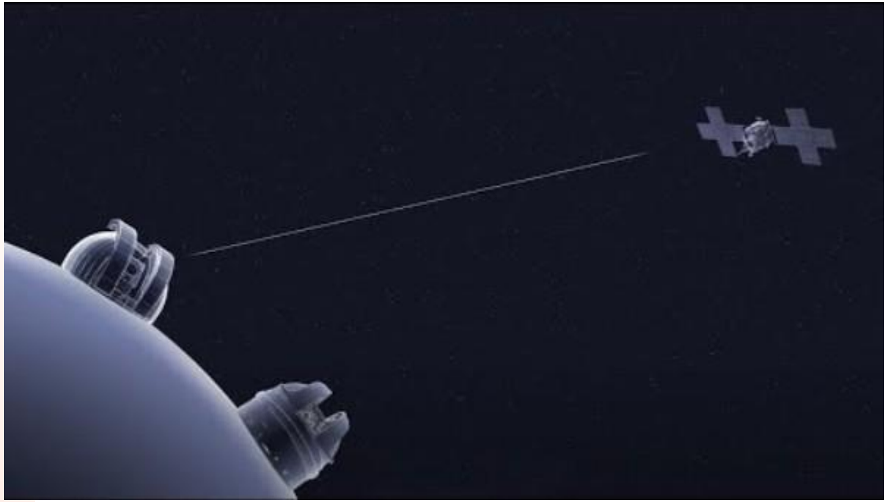
The Expanding Role of Artificial Intelligence in Space Exploration

- Transformative Impact of AI
- European Space Agency (ESA) Initiatives
- AI for Habitability Assessment
- Model Validation and Metrics
- Dynamic Risk Assessment & Decision-Making
- Transfer Learning for Space Environments
- AI as a Lead Explorer

Optical Communications

Optical Communications in Deep Space

- **NASA's Optical Communications Advancements**
- **Deep Space Optical Communications (DSOC) Demo**
- **Challenges & Mitigation Techniques**
- **Advantages Over Traditional RF**



Lasers in Space! How NASA's New Technology Could Revolutionize Deep Space Comms (Live Public Talk)
Speakers: Dr. Angel E. Velasco, DSOC ground laser transmitter lead, optical communications engineer Dr. Joseph Kovalik, DSOC flight integration & test lead, optical communications engineer (Original air date: Oct. 17, 2024)

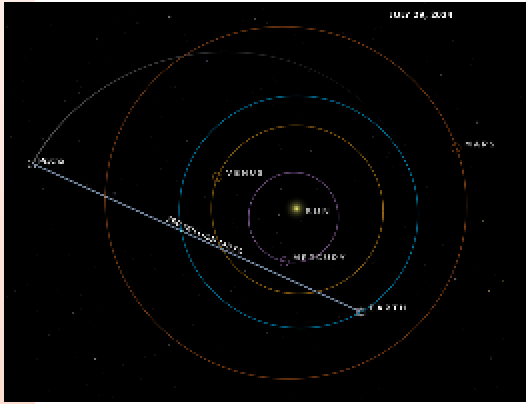


Figure 2. Psyche Spacecraft (NASA, 2024)

Robotics Platforms

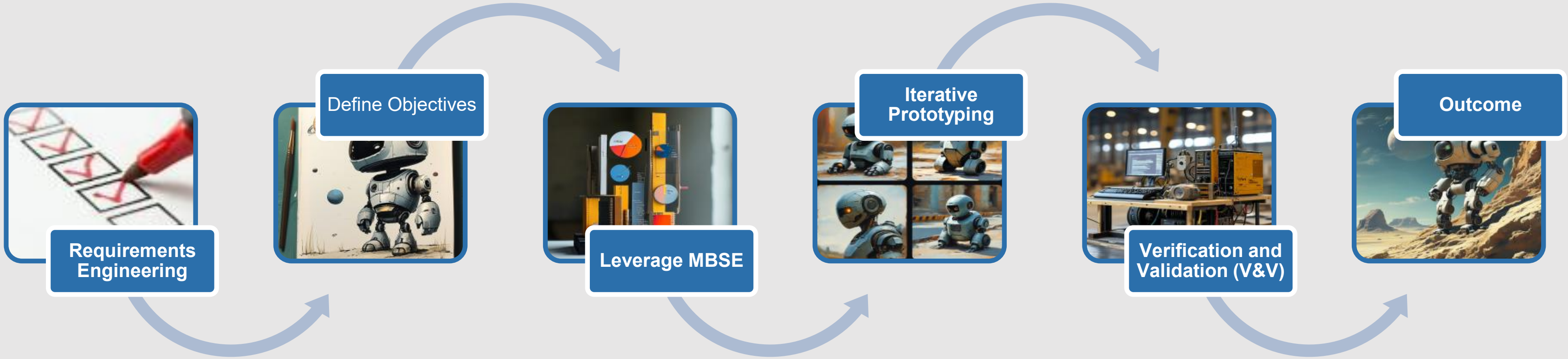
Ingenuity: an autonomous NASA helicopter operated on Mars from 2021 to 2024 (Jet Propulsion Laboratory, 2023).

A conceptual illustration of Canadarm3's robotic arm aboard the Lunar Gateway. (Canadian Space Agency, 2024).

AI-Enhanced Robotics in Space Exploration

- Core Role of Robotics
- Benefits of AI Integration
- Global Collaboration and Innovation
- Advanced AI Capabilities
- Predictive Autonomy

Systems Engineering Methodology



Systems Engineering Framework for Integration

- Overall Approach
- Requirements Engineering & Mission Alignment
- Mission Objectives & Success Criteria

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Systems Engineering Methodology

- MBSE with SysML
- Iterative Prototyping
- Verification & Validation (V&V)
- Risk Management (FMECA-based)

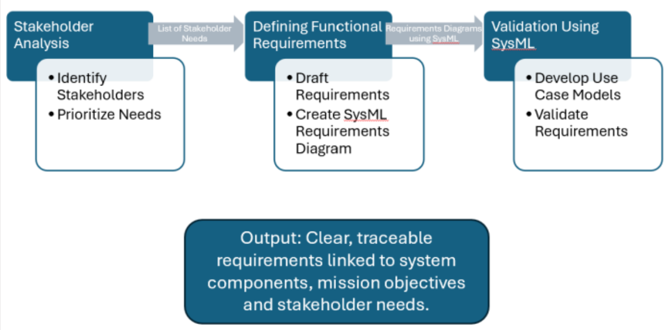

Figure 4.Visualizing the MBSE Process

AI generated representation of the Systems Engineering Process

Feasibility

Feasibility of Integrated Optical-AI Systems

- Technological Factors
  - Data Transmission
  - AI Processing Efficiency
  - System Integration
- Operational Factors
  - Autonomy in Decision-Making
  - Mission Versatility
  - Maintenance & Upgradability
- Environmental Factors
  - Radiation & Thermal Extremes
  - Terrain & Atmosphere Variability
  - Signal Interference

Conclusions

Systems engineering provides a structured framework to manage the complex challenges of AI-driven, autonomous deep-space exploration.

By emphasizing modular design, iterative development, validation, and risk management, it ensures systems are robust, scalable, and adaptable to interplanetary conditions.

This approach enables seamless integration of optical communications, AI, and robotic platforms while addressing mission-critical constraints.

As space missions become more ambitious, systems engineering will remain essential to achieving sustainable exploration and expanding human presence beyond Earth.