Future Directions in Space Research:

Science Missions, NASA Initiatives and Commercial Applications

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Decadal Surveys set Science Priorities
Why:
• Next logical step – most science return for the investment
• Samples can be analyzed by multiple labs
• Investigations by 100’s of researchers
• Advanced instrument utilized that is too large, complex or recent for space hardware
• Alternate measurement routes can be followed
Mars Sample Return Drives Technology Research

- Example new developments
  - Mars Ascent Vehicle (MAV)
  - Sample acquisition and handling

Thermal Model for Analysis and Control of Drilling in Icy Formations of the Solar System

Timothy Szwarc – PhD Candidate

Feasibility of a Single Port Hybrid Propulsion System for a Mars Ascent Vehicle

Ashley Chandler, PhD 2012
Beth Jens, PhD Candidate
Feb 15, 2013: Asteroids are Big News
<1% of Near Earth Asteroids Currently Tracked
Asteroid Mission Would Consist of Three Main Segments

Asteroid Identification Segment:
Ground and space based NEA target detection, characterization and selection

Asteroid Redirection Segment:
Solar electric propulsion (SEP) based asteroid capture and maneuver to trans-lunar space

Asteroid Crewed Exploration Segment:
Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid
Asteroid Strategy

- NASA’s asteroid strategy aligns relevant portions of NASA’s science, space technology, and human exploration capabilities for a human mission, advanced technology development, efforts to protect the planet, and engages new industrial capability and partnerships.

- Leverages existing NASA efforts:
  - Asteroid Identification and Characterization efforts for target selection
  - Solar Electric Propulsion for transport to and return of the target asteroid
  - Robotic servicing techniques for capture
  - SLS and MPCV missions for asteroid rendezvous

- Benefits future exploration objectives for carrying humans further into space than ever before:
  - Deep space navigation and rendezvous to enable crewed operations in deep space
  - High power solar electric propulsion to enable efficient transportation to deep space destinations
  - In space robotics for capture/control of uncooperative objects
Sentinel Key Features

Launch: July 2018  
Falcon 9  
Orbit: 0.6 by 0.8 AU Heliocentric  
Mission Life: 6.5 years  
Spacecraft: 7.7 m (25.4 ft) tall  
3.2 m (10.5 ft) across  
1,500 kg (3,300 lbs)  
2.0 kW solar array  
24 Ahr battery  
3-axis stabilized  
1.5 meter high gain antenna  
Instrument: 50-cm telescope  
5-10.2 µm wavelength  
HgCdTe detector cooled to 40 K  
24 million pixels  
65 microjanskies sensitivity  
Field of View 11 deg² (2x5.5 deg)  
Sky Coverage Rate: 165 square degrees per hour  
Astrometric Accuracy: 0.2 arc seconds  
On-Board Data Storage: 96 GB
Augustine Commission noted commercial capability
Obama’s ‘Game-changing’ NASA Plan Folds Constellation, Bets Commercial

NEWS ANALYSIS
AMY KLAMPER AND BRIAN BERGER, WASHINGTON

Launching the future of U.S. human spaceflight on an uncertain trajectory, President Barack Obama surprised lawmakers and industry with a budget proposal that scraps NASA’s Moon-bound Constellation program in its entirety and bet a chunk of the savings on the ability of commercial firms to ferry crews to and from the international space station.

Obama’s proposed NASA budget of $19 billion for 2011 — a 1.5 percent increase over 2010 — commits to retiring the space shuttle after five more flights, halts development of the Orion Crew Exploration Vehicle and Ares 1 rocket, and solidifies U.S. intentions to keep using the nearly completed space station for another decade. The centerpiece of Obama’s proposal is a promised $6 billion investment in the commercial sector.
Commercial Resupply to ISS Begun

SpaceX Dragon berths with ISS

Orbital Sciences Antares first test flight
Commercial Crew competition underway: Boeing, SNC, SpaceX
Suborbital Tourism About to Start

Virgin Galactic Spaceship 2 hot fire test

XCOR development moving forward
FAA Center of Excellence for Commercial Space Transportation


• What & Why: A 10-year partnership of academia, industry, and government to create a world-class consortium that will address current and future challenges for commercial space transportation

• 3 Goals: Research – Training – Outreach

Stanford competitively selected August 2010
• Needed in order to guide research towards the COE’s goals:
  – Inform regulations
  – Increase safety
  – Facilitate the industry
• Completed in December 2011
• Compiled from input received at 2 workshops
1. Space Traffic Management & Operations
   - 1.1 Orbital
   - 1.2 Suborbital
   - 1.3 NAS Integration
   - 1.4 Spaceport Ops
   - 1.5 Integrated Air & Space Traffic Mgmt.

2. Space Transportation Operations, Technologies & Payloads
   - 2.1 Ground System Ops & Safety Technologies
   - 2.2 Vehicle Safety Analyses
   - 2.3 Vehicle Safety Systems/Tech’s
   - 2.4 Payload Safety
   - 2.5 Vehicle Ops Safety

3. Human Spaceflight
   - 3.1 Aerospace Physiology & Medicine
   - 3.2 Personnel Training
   - 3.3 ECLSS
   - 3.4 Habitability & Human Factors
   - 3.5 Human Rating

4. Space Transportation Industry Viability
   - 4.1 Markets
   - 4.2 Policy
   - 4.3 Law
   - 4.4 Regulation
   - 4.5 Cross-Cutting Topics
Results – Research Priorities

• Theme 1 - Space Traffic Management (STM) and Operations:
  – High-Priority Research: In order to reduce the imposition made on the National Airspace System and facilitate the integration of air and space vehicle traffic, a minimum safe corridor for launches and re-entries must be identified.

• Theme 2 - Space Transportation Operations, Technologies, and Payloads:
  – Recommendation: Further effort is required to identify top research objectives and relation to other topics. Example: human rating of launch vehicles

• Theme 3 - Human Spaceflight:
  – High-Priority Research: Verifiable guidelines are needed for all spaceflight participants. To develop these, extensive data on the risks of various medications and conditions in the space environment are required.

• Theme 4 - Space Transportation Industry Viability:
  – High-Priority Research: What “the market” is remains an open question to the CST industries. Identifying and verifying the suborbital and orbital microgravity commerce and research opportunities is of prime importance.
• **Unified 4-D Trajectory Analysis**  
  – Tom Colvin, Prof. Juan Alonso

• **Multidisciplinary Analysis of Safety Metrics**  
  – Francisco Capristan, Prof. Juan Alonso

• **Space Environment MMOD Modeling and Prediction**  
  – Alan Li, Prof. Sigrid Close

• **Autonomous Rendezvous and Docking**  
  – Jose Padial, Prof. Steve Rock

• **Role of COE CST in Encourage, Facilitate, and Promote**  
  – Jonah Zimmerman, Prof. Scott Hubbard
Two Tasks…Intertwined

• **Task 185: Unified 4D Trajectory Approach for Integrated Traffic Management**
  – Development of simultaneous air/space traffic management procedures for commercial space transportation. Leverage NextGen.

• **Task 258: Analysis Environment for Safety of Launch and Re-Entry Vehicles**
  – To create an *independent safety analysis capability* for launch and re-entry vehicles that is based on tools of the necessary fidelity.

Special Use Airspace (SUA) conservative

Compact Envelope Concept

[Diagram showing special use airspace and compact envelope concept]
• With reasonably realistic mission plans and probabilistic trajectories, can create dynamic 4D compact envelopes
• Analyze with existing Air Traffic Management software: FACET
Focusing on secondary and hosted payloads represents a tractable portion of Theme 4’s priority research task

- Topic was strongly suggested by several industry partners during roadmap workshop (ULA, Space Systems Loral)
- Stanford interest is in both the engineering constraints and the business case for such payloads

Interim Assessments:

- Programmatic constraints (e.g., development time) much more important than engineering issues
- Evaluation of unused launch capability underway in order to scope and monetize rideshare
- Pursuing possible policy change by Agencies (e.g., NASA’s competitive opportunities)
SIEPR POLICY FORUM

SPACE ENTREPRENEURSHIP

FRIDAY, FEBRUARY 1ST

SIEPR and the Stanford Center of Excellence for Commercial Space Transportation invite you to a fascinating discussion of the challenges and opportunities for private space ventures. Speakers include:

- Alexandra Hall
  Google Lunar X-Prize

- Ed Lu
  Former Astronaut

- Lori Garver
  NASA

- Bill Nye
  Planetary Society, PBS

- Steve Jurvetson
  Draper, Fisher, Jurvetson

- George Nield
  FAA

For more info, see http://siepr.stanford.edu/policyforum or facebook/policyforum

All events at the John A. and Cynthia Fry Gunn Building, Koret-Taube Conference Room, 366 Galvez

All Stanford Students and Faculty welcome. Registration requested.
First edition just published: a new international peer-reviewed journal.