AAS Conference 2005

Common Challenges:
Human and Robotic Exploration
Building Personnel Bridges between JSC and JPL

16-November-2005

South Shore Harbour

Houston, Texas

Agenda

- Purpose of Session #5
- Team Discussions
  - Applicable Center Experience
  - Current JPL-JSC Collaboration Efforts
  - General Needs for Moon-Mars Exploration
  - Recommended Areas for Future Collaboration
  - Summary
- Lessons Learned and Wrap-up
- Back-up Charts

Purpose of Session #5

- **Collaboration!**
  - **Existing**
  - **New**
  - **Expanded**
- **Types of Collaboration**
  - Share knowledge and/or technology
  - Share experiences and lessons learned
  - Coordinate research & development
  - Team up for projects
    - Working in tandem, i.e partnership
    - Working independently, i.e. validation and verification
- **Barriers to Collaboration**
  - Funding
  - Scheduling
  - “Politics”
    - Space policy and Intra-agency competition

Purpose of Session #5 (cont.)

- **Building Personnel Bridges between JSC and JPL**
  - Early career engineers meet-and-greet
  - Guideline for participation was 3 to 10 years experience; except for mentors
- **Formed up teams to focus attention on similar work**
  - **Avionics**
  - **Entry, Descent & Landing**
  - **Robotics**
  - **Mission Operations**
- **Traveled to each facility, Video Conference, Teleconferences**
  - **These are the things that reinforce working relationships for the future!!!**
- **Session Leads**
  - JSC/Troy LeBlanc & David Korth
  - JPL/Andrew Mishkin & Young Lee

Avionics

Avionics: Overall Team Focus

"Identify common vision of future avionics technology, and promote collaboration of knowledge and resources between the centers"

Avionics: Applicable Center Experience (1)

- **JPL:**
  - Development of avionics hardware and related technology for JPL programs and projects.
  - Specialize in design and development of electronics, miniaturized flight avionics hardware, mobility electronics, reliable computing and architecture/systems, celestial sensors, FPGA/ASICs, advanced computing engines, low-temperature energy storage, mars surface photovoltaic technology, highly integrated miniaturized charge control electronics.

- **JSC:**
  - Designs, develops, tests and engineers core electronic & software systems for spacecraft systems management, command, guidance, navigation, flight control, communications, tracking, instrumentation, and data services.
  - Responsible for overall systems engineering design and integration for the combined avionics subsystems to support vehicle-level systems engineering, conceptual studies and design activities.
  - Maintains an advanced technical base in the core avionics technologies, establishes & operates the necessary development, test, and verification facilities.
  - Ensures the engineering capabilities for in-house development and provides technical direction to associated development & production contractors.

Avionics: Applicable Center Experience (2)

Projects/Activities/Research Areas

JSC

Manned vehicles, highly dependant on ground support/crew interaction

- Space Shuttle
  - Communication
    - Uplink/downlink
    - Intravehicular
  - Imagery
  - Inspection
- International Space Station (ISS)
  - Communication
  - Imagery
  - Navigation
- Electronic Parts Engineering
  - Radiation Research
  - Reliability Analysis

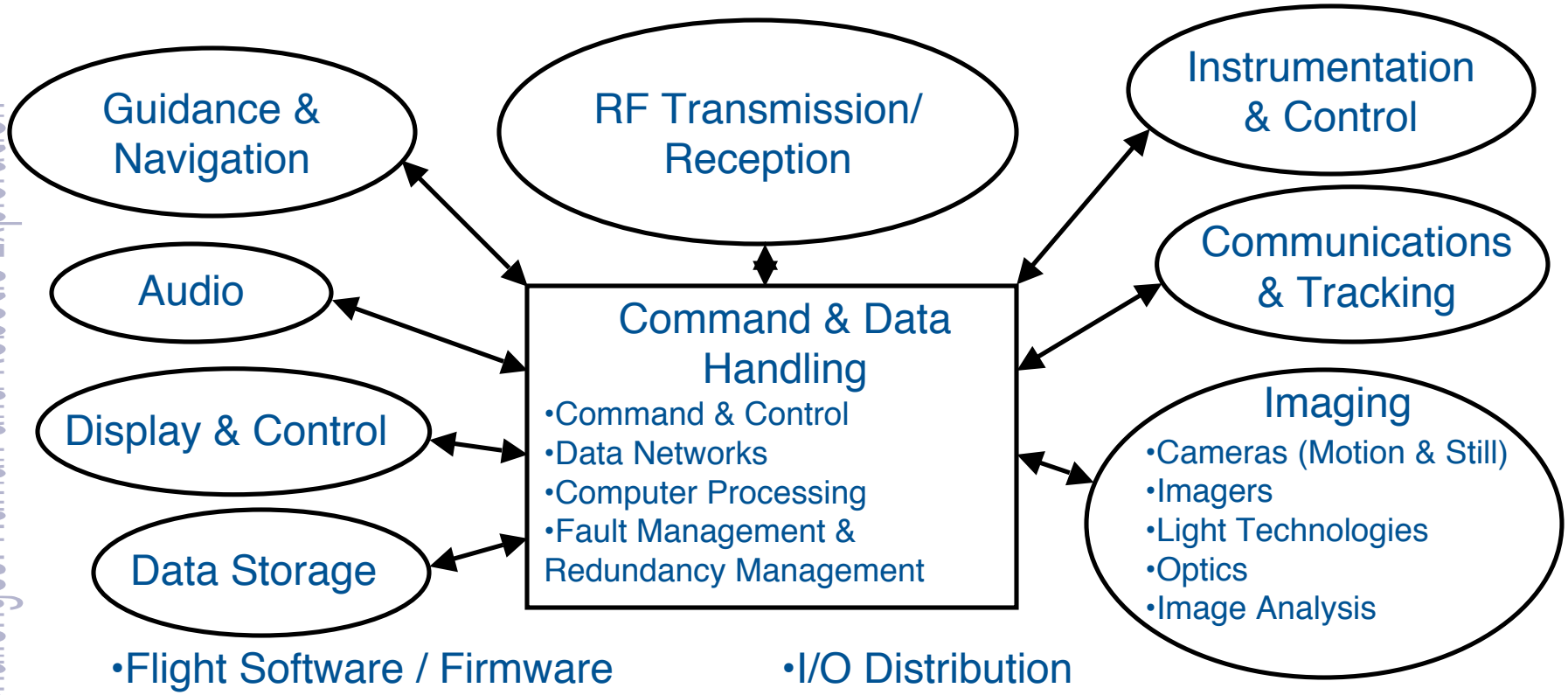
JPL

Robotic systems, highly autonomous systems

- Cassini/Huygens
- Mars Exploration Program
  - Mars Exploration Rover (MER)
  - Mars Science Laboratory (MSL)
  - Mars Reconnaissance Orbiter (MRO)
  - Mars Phoenix
- Space Interferometry Mission (SIM)
- Terrestrial Planet Finder (TPF)
- Deep Impact
- Dawn
- Electronic Parts Engineering
  - Radiation Test
  - Other Reliability Analysis
- Micro-Inspector

Avionics : Applicable Center Experience (3)

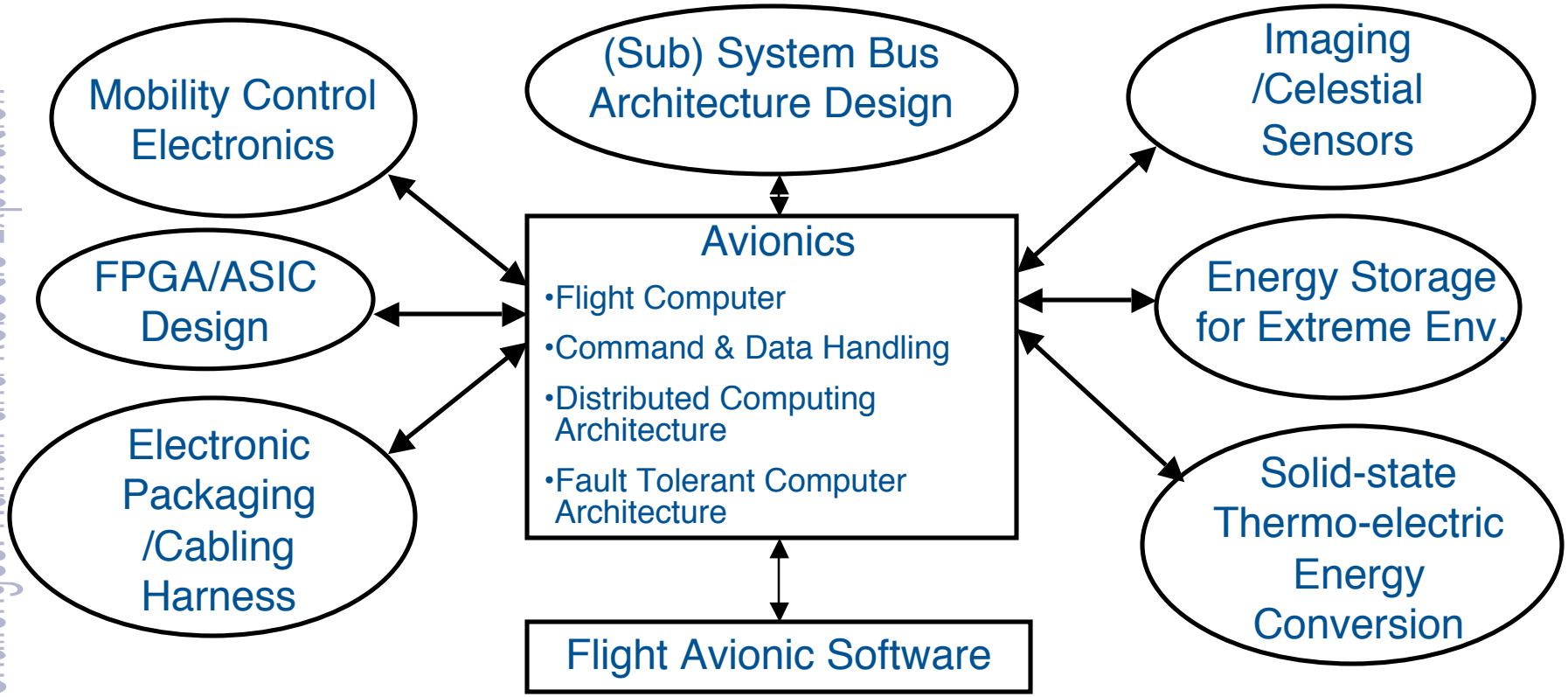
JSC Technologies / Expertise



- Flight Software / Firmware
- Electronics Manufacturing
- Power Electronics / Converters
- Radiation Effects
- Internal Wireless Systems
- Cable Design
- I/O Distribution
- Data Compression / Decompression
- Embedded Systems Design
- Fault Detection, Isolation & Recovery / Reconfiguration
- Certification of Flight Hardware

Avionics: Applicable Center Experience (4)

JPL Technologies / Expertise



- Next Generation Power Electronics Design
- ECAD Tools & Processes
- Bio-Inspired Technologies & Systems
- High Precision Motion Control

Avionics: Applicable Center Experience (5)

JSC/JPL Technology Overlaps

- FPGA (Field-Programmable Gate Array) Design
- Command & Data Handling
- Radiation Effects Research
- Data Distribution Network Design
- Avionics Systems Engineering
- Imagers/Image Analysis
- Electronic Board design
- Fault Tolerant Computer Architecture

Avionics: Current JPL-JSC Collaboration Efforts

- Only known collaboration effort between JSC and JPL is radiation research
- NEPAG (NASA EEE Parts Assurance Group) also exists, but is not JPL-JSC specific
  - Agency-wide weekly parts telecon, with international partners invited to participate on a monthly basis

Avionics: General Needs for Moon-Mars Missions (1)

- **Constraints:**
  - Radiation environment (limited availability of commercial radiation hard/tolerant parts)
  - Power/mass/volume (increased demand for more capability)

- **Needs:**
  - Increased Data Bandwidth
  - Adequate and efficient power supply and distribution
  - Onboard high performance, advanced computing systems
  - Increased volume data storage
  - Standardization of interfaces
  - Adaptability to new technologies and changing mission objectives
  - More efficient electronic board layout
  - Advanced compression technologies
  - Higher specific capacity energy storage/production systems
  - Wireless communications capability

Avionics: General Needs for Moon-Mars Missions (2)

- **Some key risk areas**
  - Radiation hard/tolerant parts availability
  - Insufficient power supply
  - High reliability avionics for long duration missions
  - Compatibility of robotic autonomous systems with human controlled systems
  - Long-lived power systems for lunar surface missions

- **Technology gaps**
  - Speech recognition systems
  - Standardization of interfaces within systems
  - Advanced distributed computing technology
  - Faster and highly integrated computing element
  - Adaptive, capable, and lower power mobility control electronics

Avionics: Recommended Areas for Future Collaboration

- Open communication via NASA Avionics Conference
- JSC-JPL joint EEE parts and workmanship process audit database
  - Agency-wide database
- Establish a commonly accessible database of technological information
  - Identify each center's project resources and evaluate their applicability for potential collaborative work
- Dedicated funding to support and encourage continual collaboration efforts
  - Technology database development and maintenance
  - Conference planning and execution
- Test piggybacking
  - Facilities
  - Joint test teams (example: joint radiation testing)
  - Share experience with COTS (commercial off-the-shelf) hardware development and certification
- Designate/fund inter-center liaisons to identify areas in which centers can develop joint proposals

Avionics: Summary

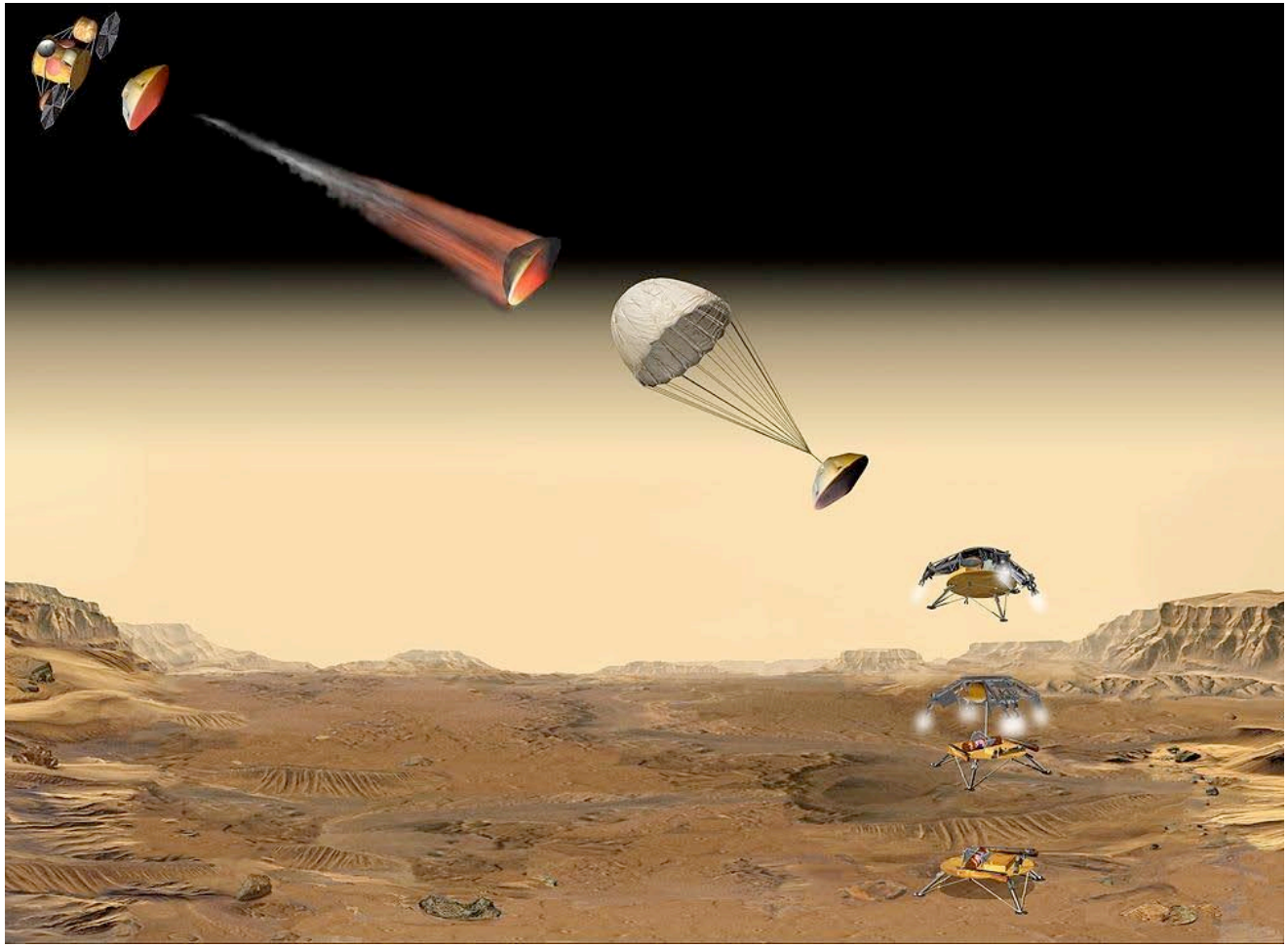
- Avionics engineers can benefit from meeting professionals outside their own area of expertise
  - New ways of doing business
  - Sharing successes as well as mistakes leads to fewer instances of “re-inventing the wheel”

- Exploration will require all disciplines to work together both within centers and across the Agency
  - Collaborative definition of mission objectives will allow most efficient use of available technology

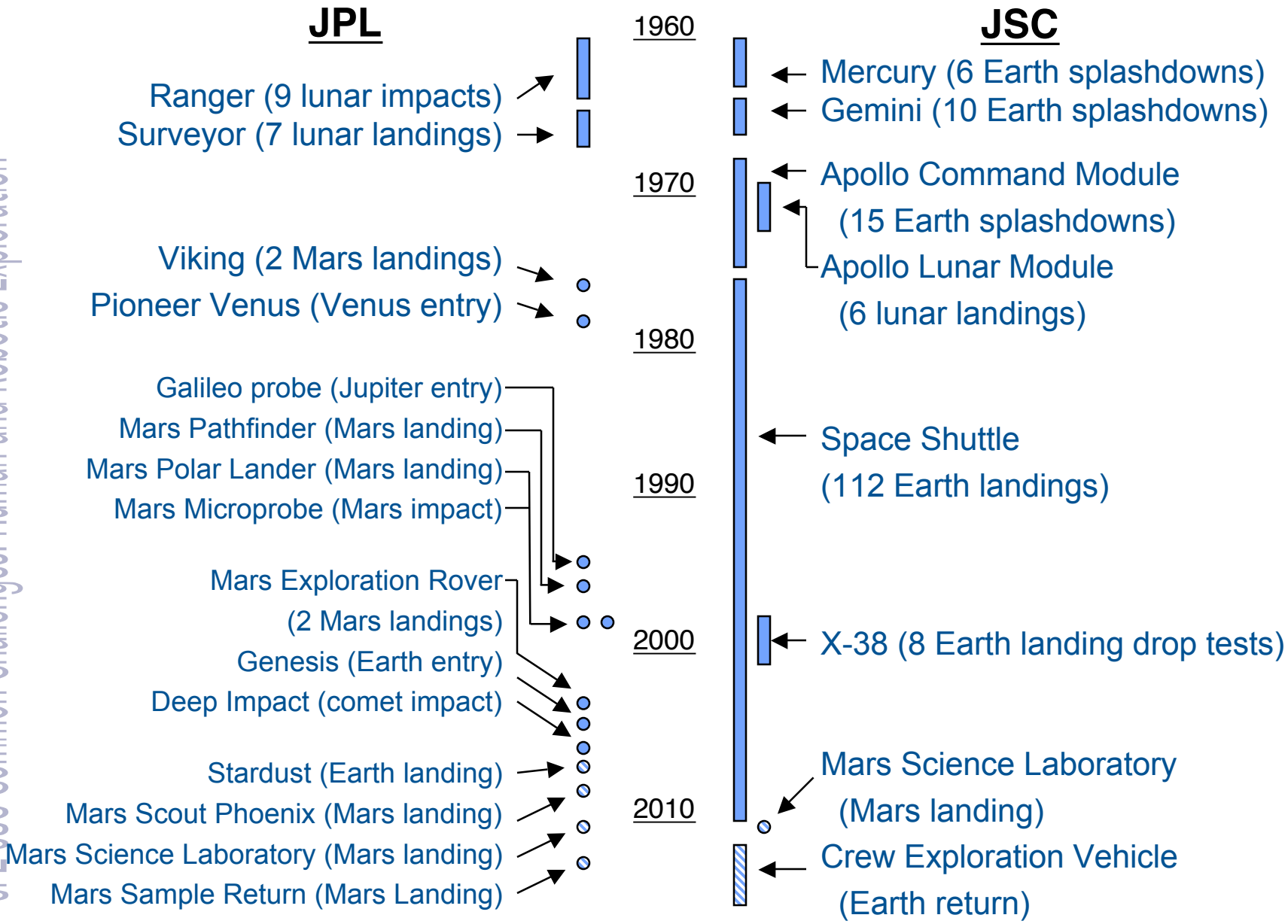
Entry, Descent & Landing

EDL: Overall Team Focus

"EDL collaboration with a focus on flight mechanics, trajectory design, and GNC for manned and unmanned spacecraft and the system/mission design decisions that affect those areas"

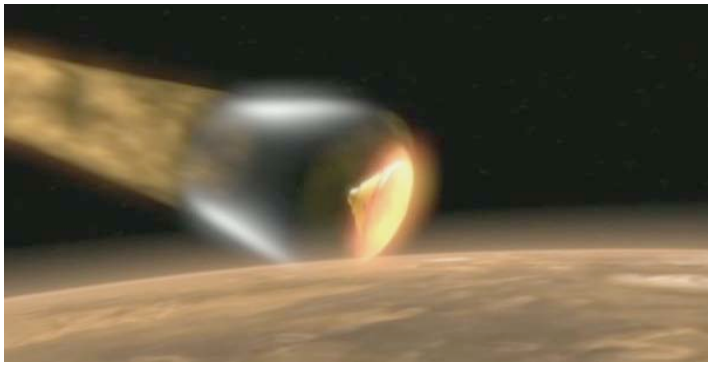


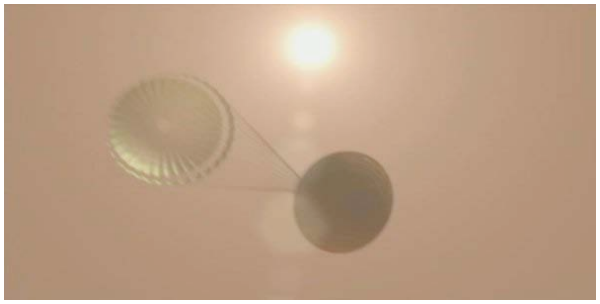
EDL: Applicable Programs



EDL: Current JSC/JPL Collaboration

- Mars Science Laboratory
  - Entry guidance (ongoing)
  - Powered descent (past)
  - Navigation (past)
- Genesis
  - Public risk estimates
- Stardust
  - Public risk estimates
  - Trajectory verification
- Phoenix
  - Entry guidance (past)





Potential Future EDL Collaboration

- Future collaboration depends on the type of EDL architecture(s) chosen for study and the associated experience of each organization
  - EDL mission analysis is similar for human vs robotic missions, with more constraints for humans
  - EDL varies greatly depending on planet (time/duration of EDL), vehicle configuration, and entry velocity
- The EDL architecture consists of:
  - System configuration (e.g. capsule vs winged vehicle)
  - GNC algorithms employed (e.g. ballistic vs entry guidance)
  - Supportive analysis technologies (e.g. simulation tools)
- A high level review of the JSC and JPL experience across various EDL architectures was performed to identify possible collaborative opportunities

Entry Systems Experience

	Earth	Moon	Mars	Human	Robotic
Propulsive	*None*	JSC, JPL(R&D)	*None*	√	√
Ballistic	JSC, JPL	*None*	JPL		√
Lifting Blunt Body	**JSC**		**JPL**	√	√
Lifting Slender Body	**JSC (R&D)**		**JSC (R&D)**	√	√
Lifting Winged Body	JSC		*None*	√	
Inflatable	***None***		***None***	√	√
Aero Control Surfaces	JSC		*None*	√	√
Maneuvering Thrusters	JSC	JSC	JPL	√	√

= High Potential For Collaborative Analysis

Descent Systems Experience

	Earth	Moon	Mars	Human	Robotic
Ballistic Parachutes	**JSC, JPL**		**JPL**	√	√
Steerable Parachutes	JSC		*None*	√	√
Winged	JSC		*None*	√	
Inflatables (e.g. hypercone)	***None***		***None***	√	√
Powered Descent	***None***	**JSC**	**JPL**	√	√
Aeroshell	*None*		JPL (R&D)		√

= High Potential For Collaborative Analysis

Landing Systems Experience

	Earth	Moon	Mars	Human	Robotic
Airbags	*None*	*None*	JPL		√
Runway / Landing Surface	JSC	*None*	*None*	√	
Splashdown	JSC			√	
Powered Landing		**JSC**	**JPL**	√	√
Skids	JSC	*None*	*None*	√	√
Helicopter Capture	JPL		*None*		√
Impact	JPL	*None*	JPL (R&D)		√
Skycrane	*None*	*None*	JPL (R&D)		√
Non-Lander (i.e. Blimp)	*None*	*None*	*None*		√

= High Potential For Collaborative Analysis

EDL GNC Technology Experience

	Earth	Moon	Mars	Human	Robotic
EDL Navigation	**JSC**	**JSC, JPL (R&D)**	**JSC/JPL (R&D)**	√	√
Entry Guidance	**JSC**	**JSC**	**JSC/JPL (R&D)**	√	√
Powered Descent Guidance (pinpoint)	***None***	**JSC**	**JPL (R&D)**	√	√
Powered Descent Guidance (non pinpoint)	*None*	JSC	JPL	√	√
De-orbit Guidance	JSC	JSC	JPL	√	√
Parafoil Guidance	JSC	*None*	*None*	√	√
Human In The Loop	JSC	JSC	*None*	√	

= High Potential For Collaborative Analysis

Other EDL Technology Experience

	Earth	Moon	Mars	Human	Robotic
Simulation tools	**JSC, JPL**	**JSC, JPL**	**JSC, JPL**	√	√
Burnup & breakup	**JSC, JPL**	***None***	**JPL**	√	√
Casualty risk assessment	**JSC/JPL**			√	√
EDL risk assessment (i.e. hazard avoidance)	JSC, JPL	JSC, JPL (R&D)	JPL	√	√
Landing site analysis	JSC, JPL	JSC (R&D), JPL (R&D)	JPL	√	√
Planetary protection	JSC, JPL	*None*	JPL	√	√

= High Potential For Collaborative Analysis

Summary of Areas for Possible Future EDL Collaboration

- Matrix charts represent many *possible* areas for JSC/JPL EDL collaboration
- Four specific ideas are presented in the following charts
  - Robotic pinpoint landing on the moon
  - Manned entry, descent, and landing on Mars
  - Burn-up and break-up analysis for casualty and risk assessments
  - Agency-wide EDL working group

Possible JSC/JPL EDL Collaboration Projects

- Robotic Pinpoint Landing On The Moon
  - Rationale
    - Leverages JPL robotic pinpoint landing R&D experience and JSC moon landing experience
    - Necessary capability for accurately placing payloads on the moon to conduct human pre-cursor activity and supply chain support
  - Goal
    - Explore entry through touchdown mission design and the G&N algorithms necessary to *autonomously* land close to target landing site
  - Products
    - Project would involve trajectory design studies, performance characterization of the trade space, and the development of flight worthy guidance and navigation algorithms
    - Consideration for application to Mars landings could be included

Possible JSC/JPL EDL Collaboration Projects, Cont'd

- Manned Entry Descent And Landing On Mars
  - Rationale
    - Leverages JSC Earth manned EDL experience as well as JPL Mars robotic EDL experience
  - Goal
    - Essentially a concept study to explore the most appropriate manned system configuration for EDL on Mars
  - Products
    - System configuration, sizing and trajectory design studies and the determination of performance envelopes
    - System configurations trade-offs based on preliminary criteria (e.g. g-loading, control authority, payload capacity, etc)
    - Compatibility with the current CEV concepts could be included

Possible JSC/JPL EDL Collaboration Projects, Cont'd

- Validation Of Burn-up And Break-up Analysis Used For Human Casualty and Hazard Risk Assessments
  - Rationale
    - Leverages both JPL and JSC core experience in burn-up and break-up analysis
    - Accurate assessments required in the post *Columbia* era
    - Calibration of the modeling would be instrumental in accurate estimation of risk for re-entry vehicles, especially sample return missions
  - Goal
    - Conduct a formal validation campaign using Earth re-entry spacecraft having observed entry breakup and residual impact debris
  - Products
    - Validation report consisting of post flight reconstruction results along with recommended areas for modeling improvements
    - Entry tracking data recorded from military assets, which may require formal NASA management involvement

Possible JSC/JPL EDL Collaboration Projects, Cont'd

- Periodic NASA-wide EDL Working Group
  - Rationale
    - Expertise and shared knowledge across all NASA centers will be necessary to generate EDL solutions for the Vision for Space Exploration
  - Goal
    - Face-to-face exchange of ideas and status of current studies
    - Connect researchers, engineers, and operators
    - Help coordinate EDL research and development across the agency
  - Products
    - Common NASA EDL website, network, or forum
    - Raise awareness of activities and expertise among centers, divisions, and people
- Common software/simulation interfaces
  - Enables the efficient exchange of models from one simulation tool to another across centers

EDL: Summary

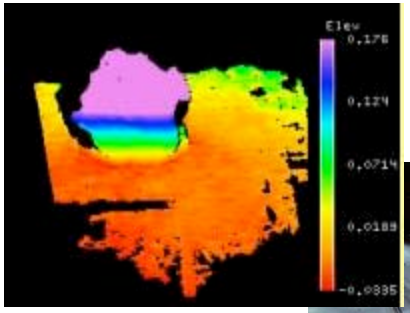
- JPL & JSC have extensive complementary experience within the analysis environment of EDL
- Several potential collaborative projects were identified
- Communication methods were presented to facilitate collaborative efforts in the future

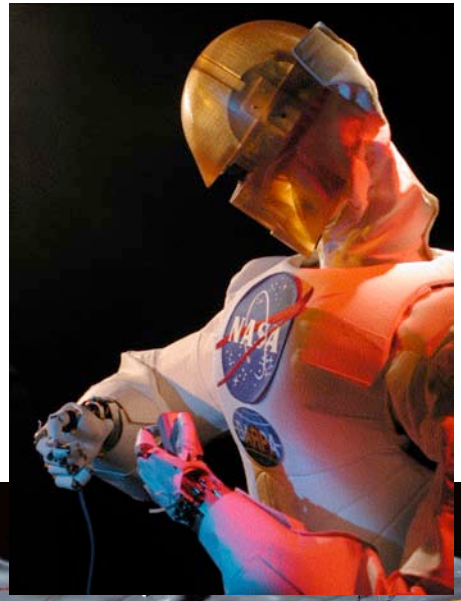
The JPL/JSC EDL team is excited about supporting the human exploration of the solar system and are prepared to join forces to maximize mission success.

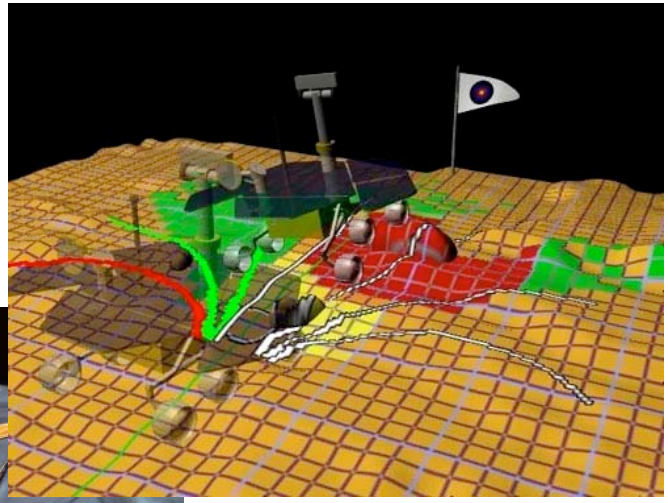
Robotics

Robotics: Overall Team Focus

"Mechanical, electrical and software components for autonomous and teleoperated systems"





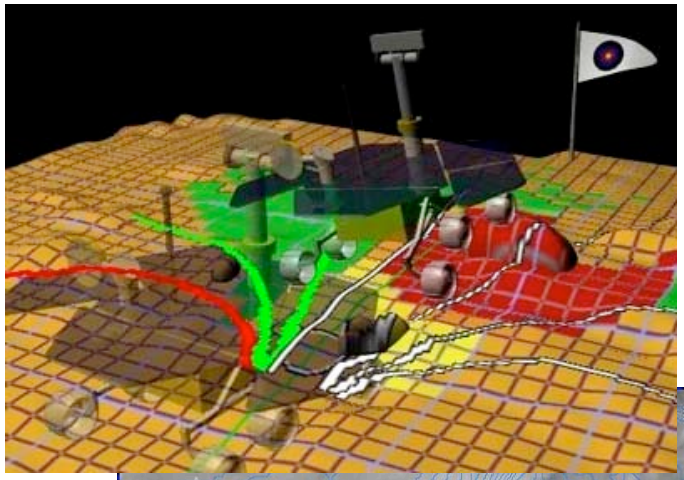


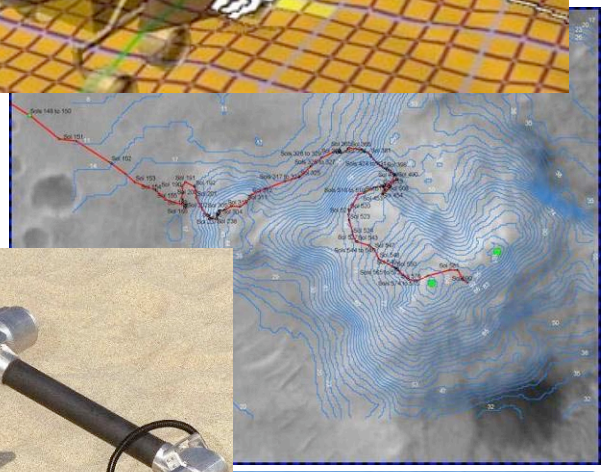
Robotics: Applicable JSC Experience

- Wheeled motion on planetary surfaces - teleoperation
- Dexterous manipulation
- Multi agent cooperation
  - Human-robot
  - Robot-robot
- Short time delay teleoperation
- Free flyers/microsatellites
- Facilities
  - Air bearing floor
  - Reduced gravity plane
- Fiducial research
  - 2D and 3D
  - RPY from one camera
- Gesture recognition
- 3D object tracking
  - Tools
  - Humans

Robotics: Applicable JPL Experience

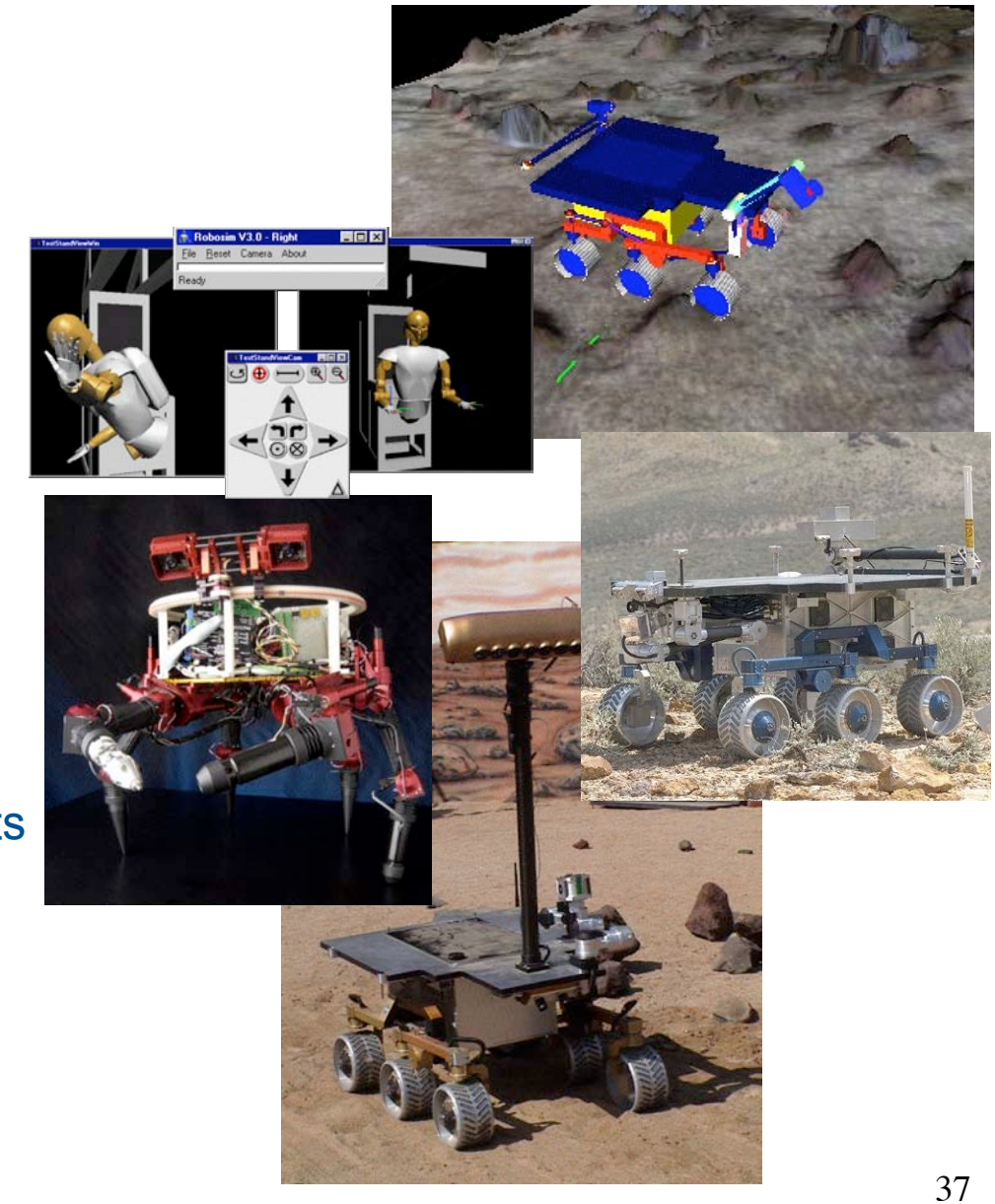
- Autonomous surface and subsurface mobility
  - Rough terrain navigation
  - Steep/sloped terrain access
  - Wheeled and legged vehicles
- Aero vehicles and multi-robot teams
- Long time delay teleoperation
- Autonomous control
  - Terrain mapping and obstacle avoidance
  - Visual odometry and multi-sensor pose estimation
  - Designated target tracking and instrument placement
  - Vision-guided manipulation
- Rover- and lander-based manipulation
  - Sampling
  - Coring
- Integrated robotic software framework





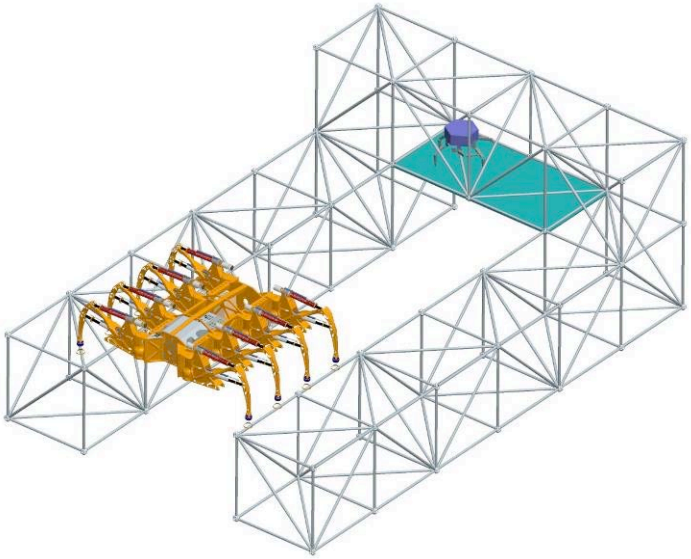
Robotics: Applicable Mutual Experience

- Human in the loop
  - Telerobotic manipulation
  - Supervisory control
- Robot and spacecraft simulation software
  - Enigma - JSC
  - ROAMS/DSENDS - JPL
- Test facilities
  - MarsYards
  - Vehicles
- Vision in unstructured environments
  - JSC manmade environments
  - JPL natural environments
- Legged motion in zero G
- Microsats



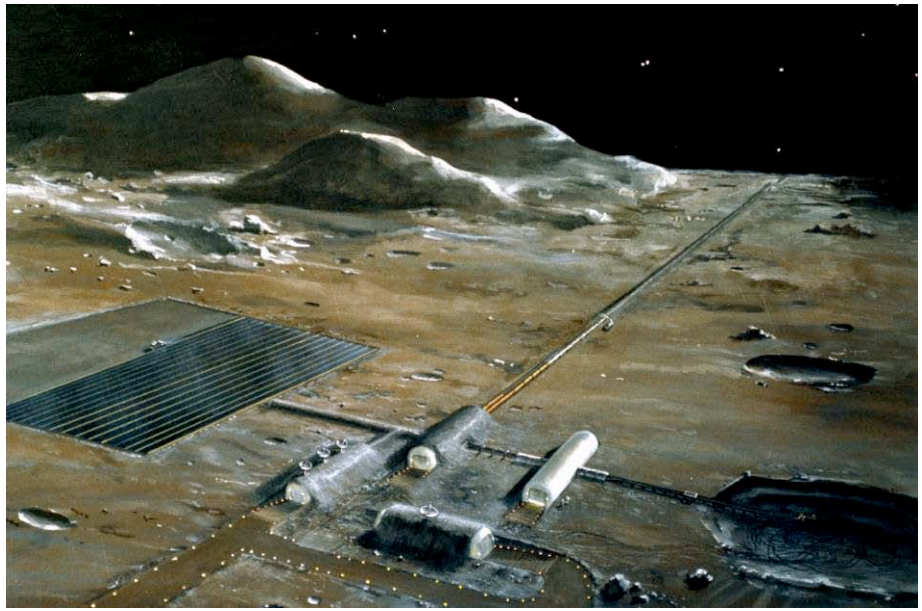
Robotics: Current JPL-JSC Collaboration Efforts

- In Space Assembly and Maintenance
  - JSC Spidernaut
  - JPL Lemur
  - JSC Tendril
- ATHLETE
  - JPL is developing robot
  - JSC providing gesture recognition, Gait Engine & Simulator
- Telepresence for Remote Supervision of Robots
  - JSC is building cockpit and providing autonomous Robonaut A
  - JPL is providing Task Level Assistant
- AWIMR – Autonomous Walking Inspection and Maintenance Robot
  - JPL Lemur
  - JSC provides zero G testbed



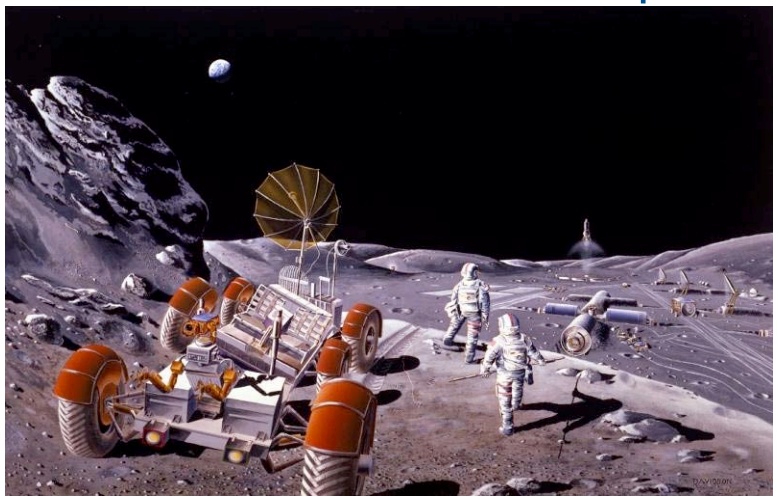
Robotics: General Needs for Moon-Mars Missions

- Missions
  - Resource scouting
  - Global traverse
    - 100 km per day
    - Autonomous
    - Teleoperated
    - Human operated
    - Follow the leader
  - Site preparation
    - Clearing/Leveling
    - Habitat construction
    - Resource collection and transport
    - Road building
    - Utility installation
    - Relocate modules



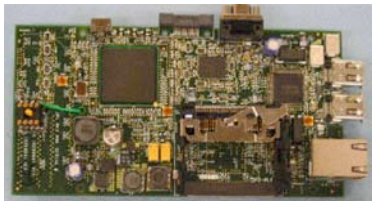
Robotics: General Needs for Moon-Mars Missions

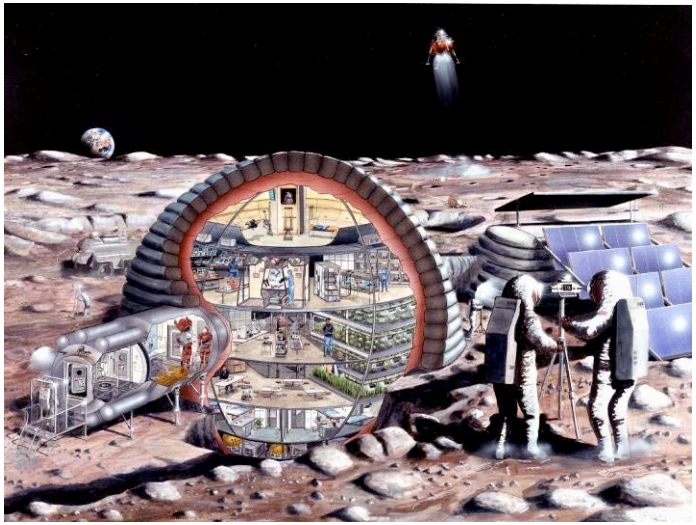
- Capabilities
  - Surface systems
    - Mobility
    - Manipulation
    - Construction
      - habitat
      - roads
      - excavation
    - Resource gathering
  - Zero G systems
    - Repair/maintenance
    - Inspection
    - Assembly
- Traits
  - Survivability
    - Thermal
    - Radiation
    - Dust contamination
    - Power management
  - Modularity
    - Interchangeable components
    - EVA Glove compatible
  - Robot-robot, human-robot interoperability



Robotics: Recommendation for Future Collaboration

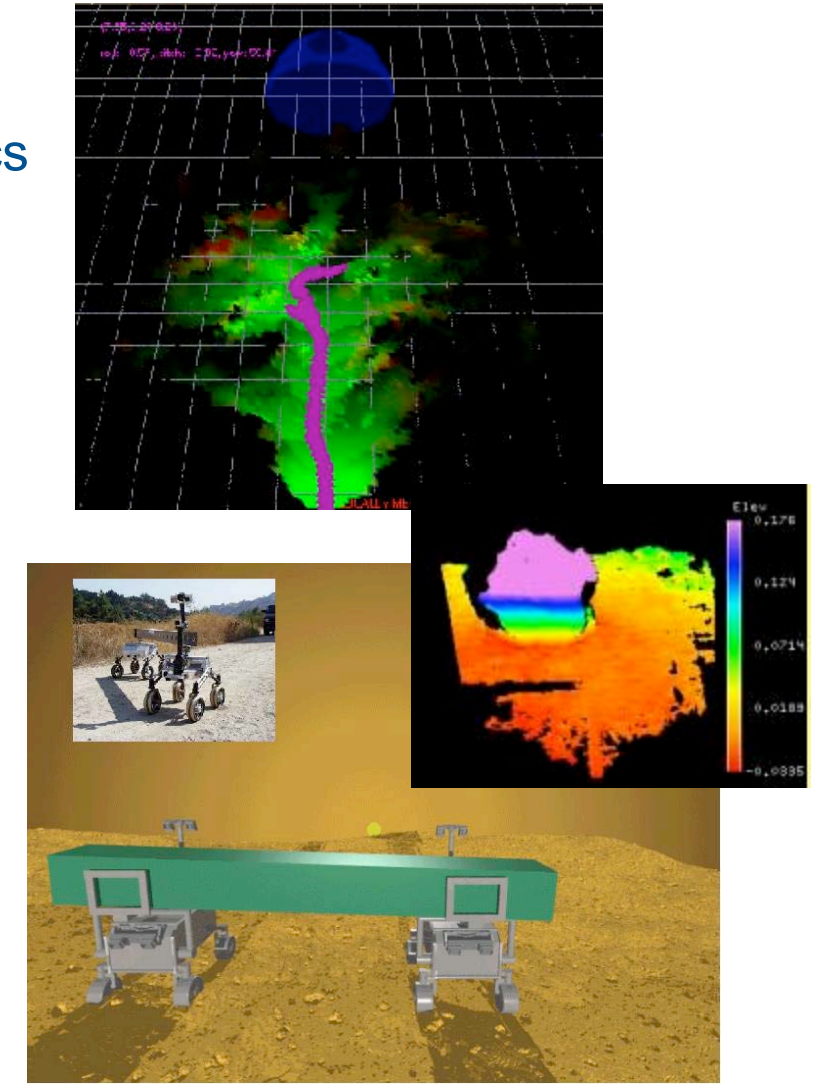
- Hardware
  - Flight qualifying components
    - Force torque sensors
    - Motor drivers
    - Motors
  - Share FPGA based hardware modules
  - Sensors
    - Contact
    - Series elastic
    - Localization sensors or beacons (not GPS)
    - Perception
      - Cameras
      - LiDAR
  - Habitat automation
    - Automated greenhouse
    - Smart house
  - Lunar/Martian survivability





Robotics: Recommendation for Future Collaboration

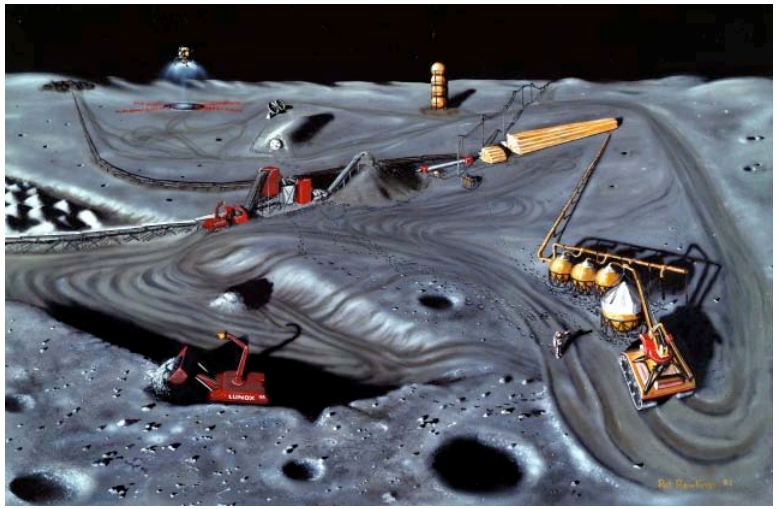
- Software
  - Common research robotics software Infrastructure
  - Interoperability
    - communication
    - interfaces
  - Enigma and ROAMS compatibility
  - High speed perception
    - mapping
    - object tracking
  - High speed continuous surface mobility
  - Multi robot coordination



Robotics: Recommendation for Future Collaboration

- Testbeds
  - Remote operations JSC->JPL and JPL->JSC
  - Share robot platforms
  - Facilities
  - Simulation Environments

- Systems
  - Rovers (manned/unmanned)
    - Exploration
    - Transportation
  - Robotic construction systems
    - Assembly
    - Excavation



Robotics: Recommendation for Future Collaboration

- Near term collaboration
  - Knowledge transfer between centers
  - Coordination of command and communication interfaces for teleoperation
  - Shared module development
    - High speed stereo
    - Motor drivers
    - Compatible modular rover components
    - Algorithms and implementations
    - Common development infrastructure
  - Develop and field test lunar rover systems
    - Lead rover
      - Manned
      - Robonaut teleoperated
    - Autonomous follower rovers
    - Mobility better than walking speed

Robotics: Summary

- Three major robotic missions for Moon and Mars
  - Resource scouting
  - Global traverse
  - Site preparation
- Major system requirements
  - Modularity
  - Interoperability
  - High speed operation
- Areas for cooperation
  - Share knowledge
  - Share facilities and infrastructure
  - Establish joint operations and field testing

Mission Operations

Mission Operations: Overall Team Focus

"To learn about each center's current experience and determine how JPL and JSC can collaborate to execute mission operations to the moon and beyond"

Mission Operations: Current Center Experience

JSC

- 24/7 flight control real-time monitoring of manned spacecraft
- Mission Control acts as an aid to the onboard crew
  - Ensure that the crew executes activities on time
  - Replan activities
  - Monitor onboard systems for anomalies
  - Aid the crew in troubleshooting activities
- High volume, near continuous downlink of data from spacecraft. Negligible delay in comm/data transmitted from spacecraft
- Distributed control center operations
- Fewer projects – Larger Scale

Mission Operations: Current Center Experience

JPL

- Concurrent operation of many types of unmanned missions
- Widely varied mission operations concepts
- Some unique operational experiences:
  - Onboard automation
    - Execution of pre-planned command sequences
    - Response to anomalies
  - Communication restrictions
    - Delayed knowledge of spacecraft state
    - Limited data volume return
    - Long light-time
  - Missions are scientifically unique, requiring science and engineering goals to be negotiated regularly
- Distributed control center operations
- Many projects, smaller scale

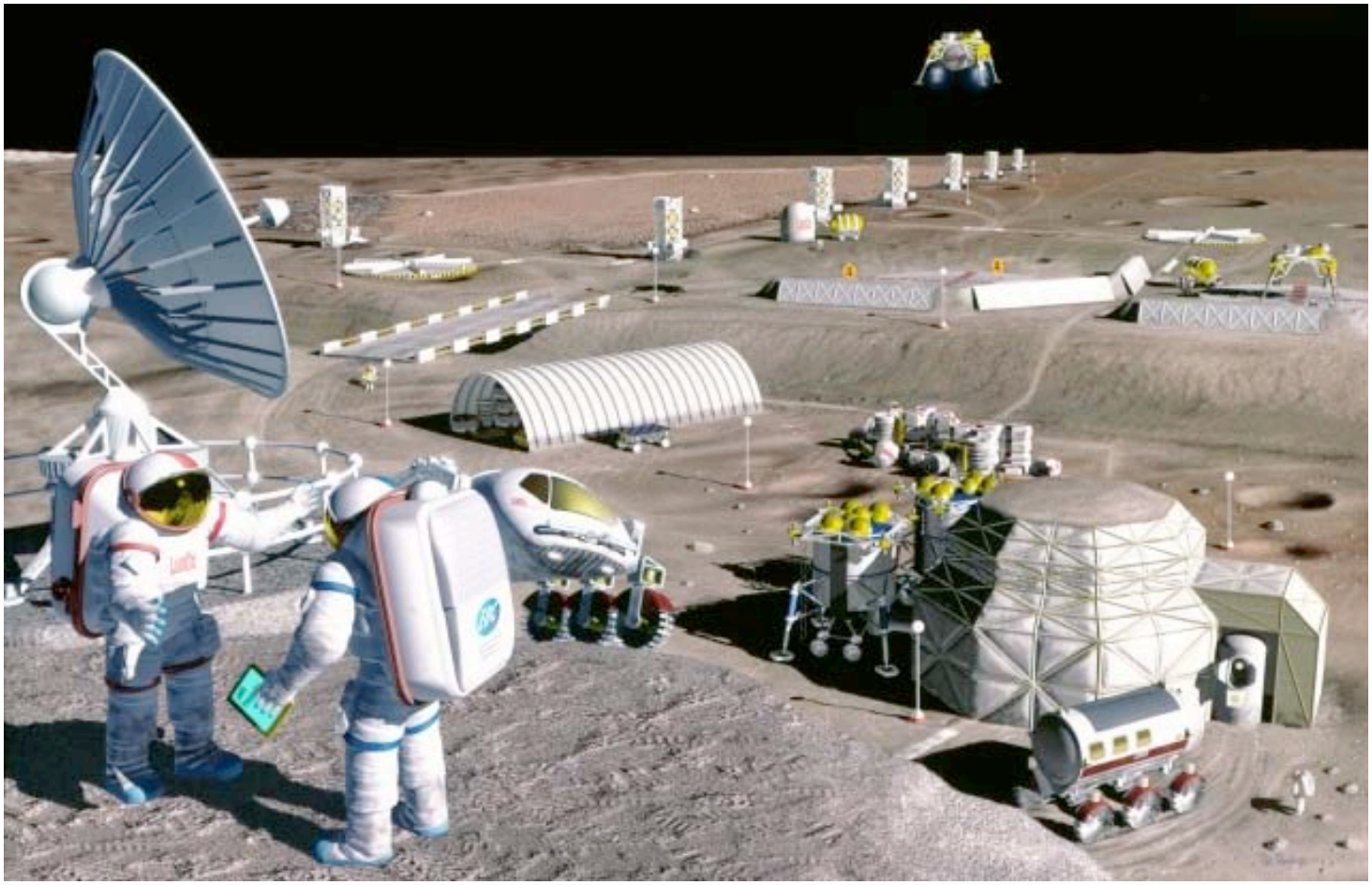
Mission Operations:
JPL-JSC Past Collaboration Efforts

- Magellan (Launched by Shuttle in 1989)
- Galileo (Launched by Shuttle in 1989)
- Ulysses (Launched by Shuttle in 1990)
- Shuttle Radar Topography Mission (Shuttle payload in 2000)
- JPL & JSC Human and Robotics Operations Infrastructure Workshop (2004)

Possible Human/Robotic Mission Operations Approach to Lunar/Mars Exploration

Approach

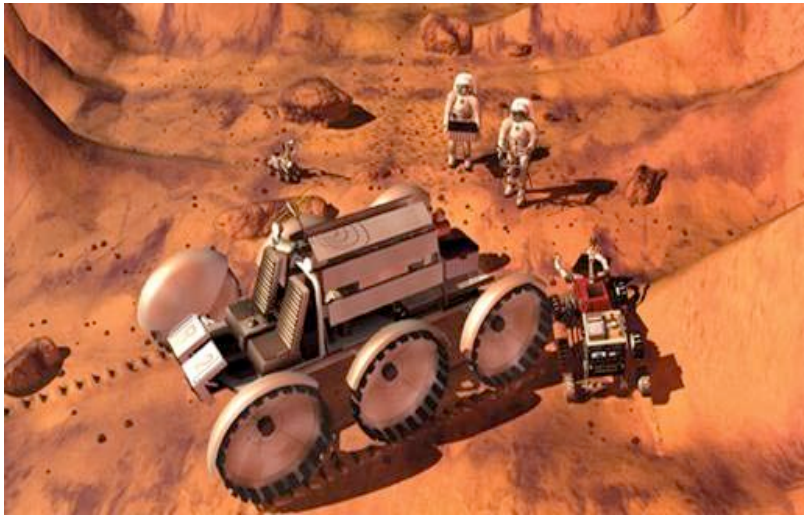
- Use robotic assets working in tandem with astronauts for Lunar and Martian surface operations



Concurrent Human/Robotic Mission Scenarios

Mission Scenario #1

- During astronaut sleep, JPL commands rovers to scout lunar terrain for high interest targets
- Rover data sent back to JPL where targets are selected and prioritized
- Target list is sent to JSC Mission Control where EVA plan is developed
- EVA plan/execute package is uplinked to crew
- Crew wakes and executes exploration plan
- Repeat during surface mission phase



Concurrent Human/Robotic Mission Scenarios

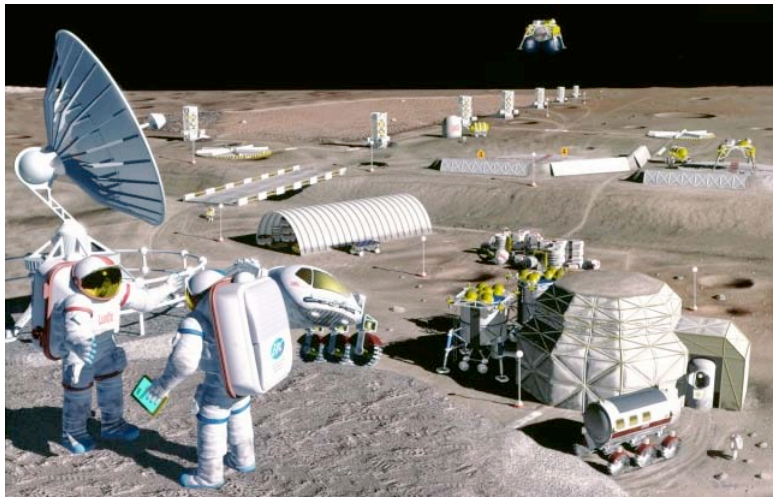
Mission Scenario #2

- Human astronaut can rapidly identify interesting science targets, and can aid in science community interaction with mission ops
- Astronaut informs JSC Mission Control of interesting science targets during EVA
- JSC Mission Control communicates target list to JPL
- JPL commands rover(s) to target(s) for in-depth study
- Astronaut moves on to scout for additional targets
- Repeat during surface operations

Concurrent Human/Robotic Mission Scenarios

Mission Scenario #3

- Astronauts explore Lunar far-side and use orbital assets that provide comm with Earth
- Orbital assets scan ahead of astronauts and rovers and provide:
  - Info on terrain/hazards for astronaut and rover use
  - Info on ice deposits in the surrounding area using remote sensing
  - Accurate determination of astronaut/rover position on the surface
- Gives Mission Control/crew more information to plan EVAs
- Allows Mission Control/crew to deviate from the EVA plan based on info received in near-real time



Benefits of Concurrent Human/Robotic Exploration

Increased Astronaut Safety

- "Extra pair of eyes" for astronaut situational awareness
- Reduces crew workload to achieve science objectives

Better Use of Astronaut Time

- Allows robotic elements to execute time consuming tasks (drilling, return samples back to lunar lander, etc)
- Allows astronaut to concentrate on identifying quality targets and perform analysis not possible by robots

Increased Mission Efficiency

- More surface area can be explored per unit time
- Increased science return
- Higher quality science targets investigated than random localized rock gathering
- Rovers can perform analysis that is not possible for an astronaut to perform in-situ (microscopic imaging)

Challenges for Concurrent Human/Robotic Mission Operations

Success is dependent upon:

- Enhanced lines of communication
- An integrated mission operations plan
- Integration of mission planning tools
- Common hardware/software interfaces between control centers
- Efficient management of multiple concurrent missions
- One body/authority that weighs JSC/JPL inputs and decides on course of action if differences arise
- Common lexicon between JSC/JPL

Recommendation for Future Collaboration

- **Proposal**: Develop a collaborative human/robotic mission operations approach that will be demonstrated in a series of integrated field tests

- **Value to NASA**:
  - Identify existing assets and experience that enhances joint operations
  - Demonstrate that combined human robotic missions lead to greater efficiency
  - Use the integrated field tests to develop the concept of operations for surface EVA
  - Identify tools, processes, products, interfaces, technology limitations, resources and facilities to effectively perform exploration
  - Determine ways to operationally mitigate technology limitations (e.g. bandwidth)
  - Identify and benefit from the differences between operations cultures

Mission Operations: Summary

- Efficient exploration can be achieved by concurrent human/robotic exploration architectures
- Recommend that JSC and JPL collaborate to bring these human/robotic architectures to fruition
- Recommend that NASA develop an integrated human/robotic mission operations culture through personnel exchanges
- Recommend that NASA develop ops concepts concurrently with systems development
- Recommend that NASA perform integrated field tests to aid in development of efficient mission ops concepts
- This effort will directly benefit on-orbit and surface (Lunar and Martian) exploration objectives

Summary

Lessons Learned and Wrap-up

- JPL & JSC have extensive complementary experience
- It is extremely important for the future of the agency to build work relationships among the next generation of engineers at JSC and JPL now!
- Participation in this activity significantly increased awareness of existing collaboration between the two Centers
- Teams became excited about the possibilities for future collaboration activities
- This effort should be only a beginning
  - Make this collaboration session a regular part of AAS conference
  - Actively pursue funding for suggested collaboration proposals

- **Special Thanks to Kathy Laurini, John Beckman, Mike Sander, and David Leestma for making this session possible!**

Team Identification

- **Avionics**
  - Mathew Benson
  - Alden Bushnell
  - Stacie Cox (lead/speaker)
  - Orlando Diaz
  - Yutao He
  - Ryan T. MacKrell
  - Mary McClellan
  - Sung Park (lead/speaker)
  - Jay Whitacre

- **Entry, Descent & Landing**
  - George Chi
  - Sarah Graybeal (lead/speaker)
  - Mark Ivanov (lead/speaker)
  - Wyatt Johnson
  - Gavin Mendeck
  - Jeff Tooley
  - Ryan Whitley

- **Robotics**
  - Alberto Behar
  - William Bluethmann
  - Lyndon Bridgwater (lead)
  - Curtis Collins
  - Antonio Diaz-Calderon
  - Matt Dicicco (speaker)
  - Won Kim
  - Richard Madison
  - Richard Petras (lead)
  - Jennifer Rochlis (speaker)

- **Mentors**
  - Young Lee
  - Mark McDonald
  - Brian Wilcox

- **Mission Operations**
  - Larissa Arnold
  - Magdy Bareh
  - Chris Farrar
  - Paul Fieseler
  - Jason Gibson (lead)
  - Mitch Ingham
  - Byron Jones (speaker)
  - Rob Lange
  - Barbara Larsen
  - David Mohr
  - Alex Moore
  - Richard Morris
  - Brian Ulman
  - Greg Whitney (speaker)
  - Colette Wilklow (lead)

The Team at JSC

Back-Up Charts

Avionics: Team Members

- Team Members:
  - JSC/Mathew Benson - Flight hardware and software integration testing experience for the past 2 _ years. Current projects include Regenerative Environmental Control and Life Support Systems testing, and Columbus Orbital Facility testing. Likes sailing and brewing beer.
  - JSC/Alden Bushnell – Avionics system engineering experience for 4 _ years. Currently the project manager for expanding the usage of DOORS, a requirements management tool, at JSC. Is interested in music and advancing technologies.
  - JSC/Stacie Cox – GFE/CFE flight hardware development, verification, and certification experience for 5 years. Currently Product Lead/Subsystem Manager for the Orbiter Boom Sensor System's Neptec provided Laser Camera System, a 3D laser imaging sensor for damage detection on Shuttle TPS surfaces. Likes travel and singing.
  - JSC/Orlando X. Diaz – Systems and Test Engineer primarily involved in the verification and validation of environmental test requirements. Also experienced in orbital mechanics and computational fluid dynamics for reacting flow environments. Interested in advancing science, research, and development.
  - JSC/Ryan MacKrell –Mechanical Engineer for Boeing / HSI for 1 _ years. Two and one-half years additional experience working with consulting firms in the areas of Telemetry and Controls. Strong interest in the Outdoors and actively competes in Adventure races.
  - JSC/Mary McClellan – GFE flight hardware development and certification experience for 3 years and currently camera product lead for Space Shuttle and Space Station programs. Likes movies, traveling and acting in musical theater.
  - JPL/Yutao He – Avionics system engineering and flight electronics design experience for 1 _ years. Currently the avionics engineer for the Micro-Inspector and ST8. Likes playing guitar, singing, and good food.
  - JPL/Sung Park – Flight electronics design experience for 10 years. Currently the Cognizant Engineer for the High Speed Interface board for Space Interferometry Mission. Likes movies and music.
  - JPL/Jay Whitacre - Energy and Power technologies. Six years experience at JPL working on next - generation energy storage technologies, member of JPL spacecraft design team, Team X, works in group that delivered MER Li-ion batteries.

EDL: Team Members

- Team Members:
  - JSC/George Chi – George is a member of the Descent Analysis Group. He is currently involved in Earth landing site assessments for the Crew Exploration Vehicle and is an Abort Region Determinator Support Office for the Space Shuttle flight control team.
  - JSC/Sarah Graybeal – Sarah is an analyst in the Descent Analysis Group of JSC's Mission Operations Directorate. She currently supports the JPL MSL entry guidance team and is training to become a Space Shuttle Flight Controller. In recent years she has also performed debris footprint analysis for many projects including the STS-107 accident investigation and the Return-to-Flight effort.
  - JSC/Gavin Mendeck – Gavin has worked in the Descent Analysis Group of JSC Mission Operations Directorate for 5 years. He is the entry guidance algorithm lead for the JPL Mars Science Laboratory 2009 mission, and has previously worked on public safety analyses for entry vehicles including the Space Shuttle.
  - JSC/Ryan Whitley – Ryan is a member of a flight mechanics team that assesses vehicle performance for design evaluation and requirements definition. His current and past projects include landing system trades, launch abort requirement studies, launch vehicle controllability trades, shape stability studies, and simulation tool development, primarily relating to Crew Exploration Vehicle design.
  - JPL/Mark Ivanov – Mark is a senior engineer in the Inner Planets Flight Dynamics Section, EDL/Aero Applications Group. He has been with JPL for just over a year but has over 18 years of mission design/system engineering experience working for General Dynamics Space Systems, Lockheed Martin Astronautics, and EchoStar Communications. His expertise is in optimal trajectory design and simulation software development.
  - JPL/Wyatt Johnson – Wyatt is a member of the Phoenix Mission Design and Navigation team, where he is the EDL analyst, supporting landing site targeting. He is also working on trajectory optimization for Mars pinpoint landing.
  - JPL/Jeff Tooley – Jeff is a member of the Entry, Descent, and Landing / Aero Applications group at JPL. He is currently an EDL analyst for Stardust and an analyst for pinpoint landing system studies. Jeff's specialties include trajectory optimization, simulation, and breakup hazard analysis with particular emphasis on entry systems.

Robotics: Team Members

- Team Members
  - JSC/Lyndon Bridgwater – Lyndon is a member of the Robonaut group, where he is the forearm subsystem lead. He Is the mechanical designer of Spidernaut. Current activities include next generation hand/forearm design for Robonaut.
  - JSC/Jennifer Rochlis - Jen is a Human Factors and Robotics Engineer with the Automation, Robotics & Simulation division at NASA JSC. She is the human-machine interface designer for the Robonaut advanced cockpit project, the Display and Control System lead for the SCOUT rover testbed project and the Engineering Robotics lead for the Advanced EVA Group.
  - JPL/Curtis Collins – Curtis is a member of the Mobility and Manipulation group. He recently joined the lab after teaching mechanical design and robotics at UC Riverside and Caltech. He is currently developing zero-g and micro-g walking algorithms for the LEMUR multi-limb robot, and a software tool for comparing mobility systems for planetary surface operations.
  - JPL/Antonio Diaz-Calderon – Antonio is a member of Information Systems and Computer Science Staff with the Mobility and Manipulation Group at JPL. His current activities focus on automated planetary manipulation, sample acquisition, sample handling, automated instrument placement from planetary landers and rovers, sensor fusion, state estimation, rover navigation and mobility. He is also a member of the MER Mobility and IDD downlink team.
  - JPL/Matthew Dicicco – Matt is an associate member of technical staff at the NASA Jet Propulsion Laboratory in Pasadena, CA. He recieved an MS from MIT in 2005 where he studied manipulator control in the Field and Space Robotics Laboratory. He recieved a BS in mechanical engineering from Carnegie Mellon in 2003. At JPL he has continued his work on robot manipulators through research and development tasks and flight projects as a member of the Mobility and Manipulation Group.
  - JPL/Won Soo Kim – Won is a Senior Member of Technical Staff in the Mobility and Manipulation Group. He has over 20 years experience in telerobotics research and development including software design and implementation for mobility and manipulation systems, supervisory and autonomous system concepts and algorithm development, model and sensor-based real-time control, system integration and validation, flight software implementation.
  - JPL/Richard Madison – Rich works computer vision related infrastructure tasks for the robotics section. He previously learned and did various computer vision related things. He would really like to do vision/AI for robot quadrupeds. If you can help, please let him know.
  - JPL/Richard Petras – Rich led the Distributed Rover Avionics Software task which developed a software architecture for advanced distributed avionics modules. He worked on testing and operation of the autonomous navigation software for the twin MER rovers Spirit and Opportunity, the development of several research rovers at JPL, and the CLARAty robotic architecture for planetary rovers.

Mission Operations: Team Members

- Team Members:
  - JSC/Larissa Arnold – Flight Controller for Activation and Assembly of Space Station components and Shuttle Payloads Operations for the past 5 years. Current tasks include operations work related to the Columbus module and AMS-02, plus development on operations concepts for the Exploration program. Likes camping, taking geology courses, and hiking.
  - JSC/Chris Farrar -- International Space Station Command and Data Handling Flight Controller during early ISS Assembly Missions and Expeditions. Current primary assignment is Mission Operations Directorate representative to Joint Software Review Panel where ISS Software Change Requests are reviewed and dispositioned. Likes all sports and reading Science Fiction novels.
  - JSC/Jason Gibson - Space Shuttle Data Processing System flight controller responsible for onboard computer systems. Enjoys hiking, flying and building my own airplane.
  - JSC/Alex Moore - Mission operations planning and scheduling for ISS operations for the past 8 years. Current projects include Increment 12 real-time operations support, ESA planning for 1E, integration of ATV into planning process and operations concept development for Crew Exchange Vehicle. Enjoys helping others, playing soccer, riding motorcross, running and racing cars.
  - JSC/Brian Ulman – Certified ISS console operator in the Operations Planning discipline for the past 4.5 years. Current projects include the Onboard Short Term Plan Viewer (OSTPV), mission operations web based application development, and distributed software deployment.
  - JSC/Greg Whitney - ISS Mission Planning for the past 3 1/2 years. Currently supports real-time ISS operations and pre-increment planning for Increment 14. Enjoys Bicycling, playing hockey, and watching football.
  - JPL/Magdy Bareh - Has been part of the Assembly Test Launch Operation and Mission Operations teams for Deep Space 1 and Spitzer Space Telescope. Most recently was part of the Dawn Mission Operations team.
  - JPL/Paul Fieseler is currently the Lead Sequence Engineer on both the Mars Odyssey and the upcoming Mars Phoenix missions. He has also worked the Galileo mission in both sequence engineer and principal investigator roles. Prior to these roles, Paul took a break from the space business with a tour of duty as a US Peace Corps volunteer. Back in the Jurassic, Paul worked nine missions as a back-room Mission Controller in the Payload Operations group for the Space Shuttle.

Mission Operations: Team Members

- Team Members (cont.):
  - JPL/Mitch Ingham is a software systems engineer on the Mission Data System (MDS) project, which is developing a software product line architecture and model-based systems engineering process for NASA exploration missions. Upon joining JPL in 2003, he worked on the Mars Science Laboratory 2009 rover project, leading the development and validation of an integrated software demonstration of entry, descent and landing. Mitch has broad interests in systems engineering, spacecraft automation and operations, and is a PI or Co-I on several research and technology development projects in these areas.
  - JPL/Byron Jones is currently working as a Mission Planner and Systems Engineer for the Mars Exploration Rovers. Before joining the rover missions, he worked with the Multi-Mission Deep Space Network Allocation and Planning team. There, he assisted projects in determining DSN tracking requirements and negotiated tracking time for Genesis, Messenger, and New Horizons.
  - JPL/Robert Lange - Since joining the Laboratory in 2003, Rob has worked on the Cassini-Huygens Mission to Saturn as a Science Planning Engineer. Rob has a B.S. in Mechanical Engineering from the University of Michigan, and is making steady progress towards his Masters in Industrial and Systems Engineering at the University of Southern California. When not working, Rob enjoys the outdoors and traveling abroad.
  - JPL/Barbara Larsen is currently a Science Planner on Cassini. She has extensive experience in uplink software development and systems engineering for Galileo, SIRTF, and Cassini as well a previous operations experience on the Galileo spacecraft team.
  - JPL/David Mohr was hired to the Lab in 2001 and quickly found a home with the Cassini mission. Dave worked with the ground software team for a year before transitioning to the Science Planning team. For the past three years his focus has been science data acquisition for Saturn's largest moon, Titan.
  - JPL/Richard Morris started at JPL in 1999 as a software developer on the Mission Planning and Execution (MPE) team of the Mission Data System (MDS), which unifies a model-based systems engineering methodology with a state based flight software framework He continues to contribute to the design and implementation of the MDS planning and scheduling system. For over a year now he has also worked on operations for the Mars Exploration Rovers (MER), most recently as a Tactical Uplink Lead (TUL).
  - JPL/Colette Wilklow - Joined the Laboratory in 1999 to work in the Artificial Intelligence group. Colette joined the Mars Exploration Rover (MER) Project in 2001 and participated in software system development and mission operations. She currently serves MER as a Tactical Uplink Lead.

Organizers

- Team Members:
  - JSC/Troy LeBlanc has worked in Space Station Mission Planning for over 13 years leading development and deployment of crew activity planning software. Troy is the responsible NASA official for the Mission Control Center web system and a NASA group lead in Mission Planning.
  - JSC/David Korth has worked in mission operations for over 14 years in space shuttle and space station mission planning. David has served as lead planner for ISS Expeditions 1 and 7 and is currently lead of the ISS long range planning team.
  - JPL/Andrew Mishkin worked for 20 years doing systems engineering for robotic vehicles and mission operations. He was the lead architect for the surface operations processes for both the Sojourner rover and the Mars Exploration Rover vehicles “Spirit”and “Opportunity.” Most recently, he has worked MER operations as the Integrated Sequence Team Chief and Mission Manager.
  - JPL/Young Lee has been deeply involved in mission operations system requirements, development and deployment of multi-mission ground systems for deep space missions for over 20 years. Currently, she is working in the JPL Exploration Systems Engineering Office in the Operations Engineering element.