

# IV&V Annual Workshop 2013

## Development of a Robotics Guide for IV&V

Charley Price

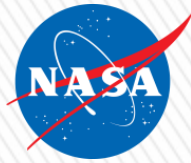
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## 1. What we did in FY 2012:

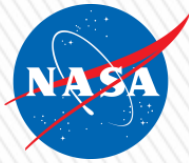
- provided robotics training to MSL IV&V analysts
- developed a 2-D simulation and scale models of OSIRIS-REx

## 2. What we did in FY2013:

- provided robotics subject matter expertise & support to the OSIRIS-REx IV&V project
- captured this support into a ***Robotics Guide for IV&V*** to be used as a legacy guide for future IV&V projects involving robotics
- guided summer interns' development of a 3-D simulator of O-REx

## 3. What we will do today:

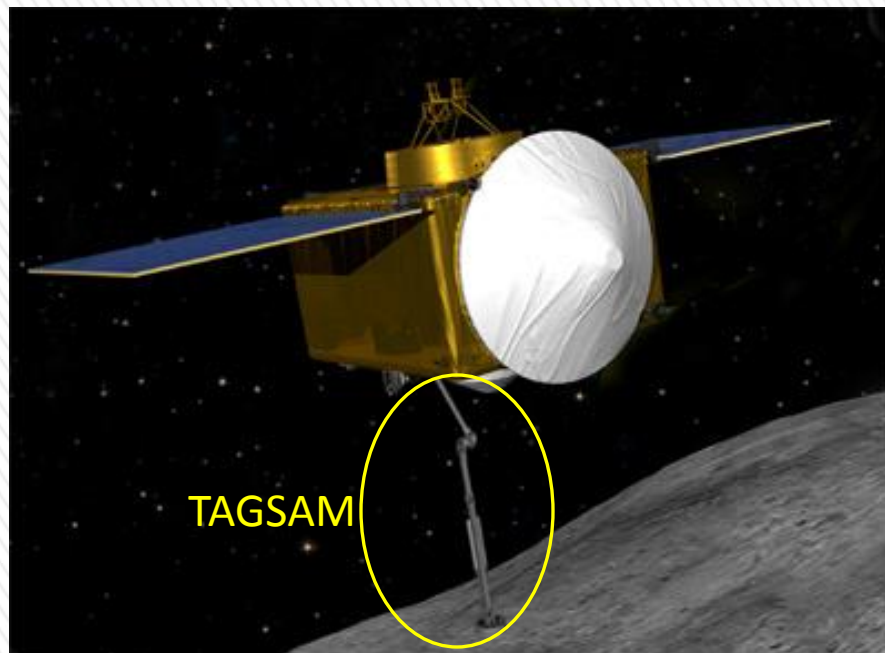
- discuss the Robotics Guide content
- discuss future robotics missions



***“Robotics Guide for IV&V, a process asset for generating products and services to enhance the IV&V of mission critical robotic spacecraft systems”***

- Captures everything CD did for OSIRIS-REx.
- Ten activities or ‘steps’
- Fourteen ‘advisories’ to the IV&V analyst

*Advisory 1: Develop the robotics portion of the technical reference from the earliest available project artifacts.*



*OSIRIS-REx Mission Touch and Go (TAG)  
Sample Acquisition Mechanism (SAM)  
image*

## Derived Initial Robotics Technical Reference:

4 degree of freedom  
planar manipulator

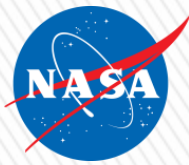
3 active pitch joints

Passive, compliant 4<sup>th</sup> joint  
'shock absorber' during  
surface contact.

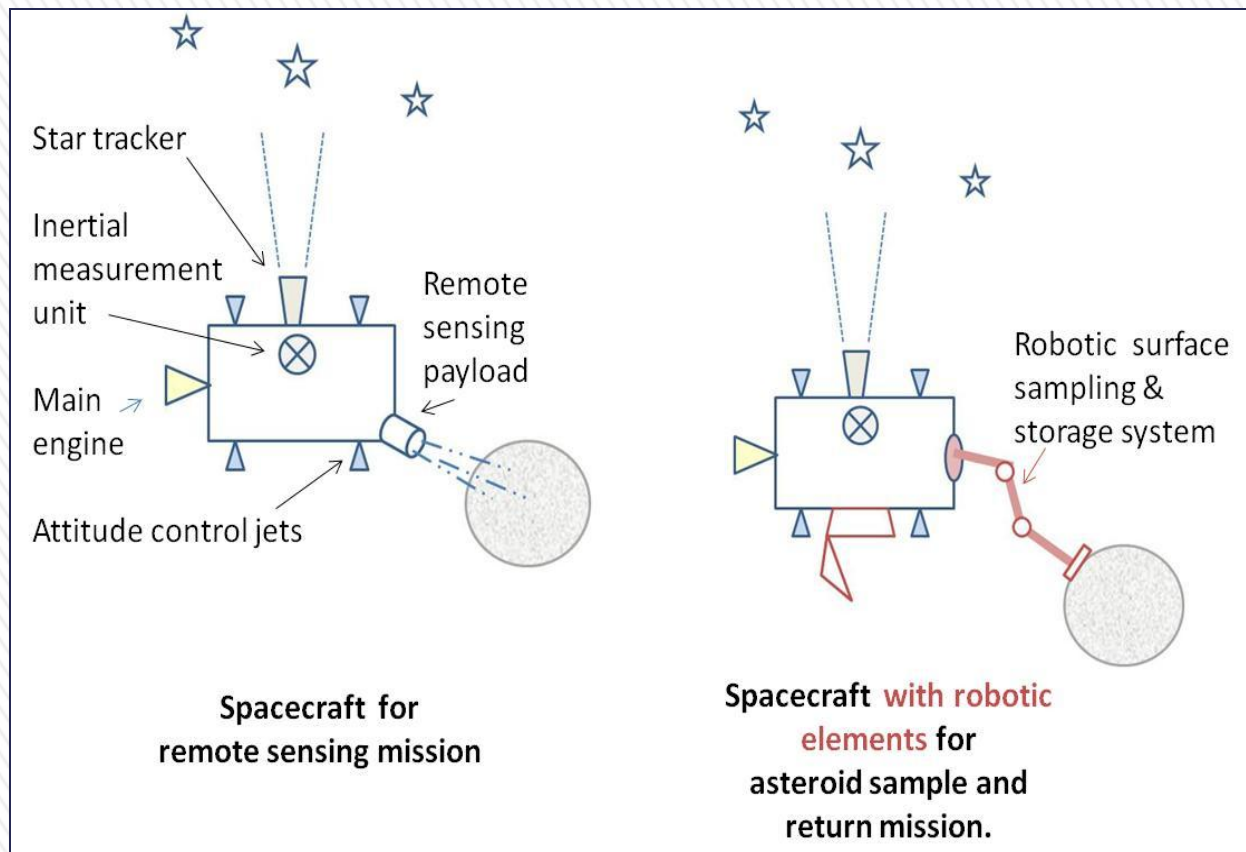
Static sampling 'pose'

Compliant sampler head

# Understand the Interactions

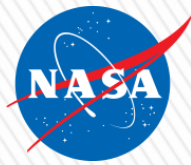


*Advisory 2: Identify robotic components of the target mission, and postulate the cause and effect between the robotic components and the conventional components.*





# Understand the Operational Environment



*Advisory 3: Seek to understand the operational environment of the robot to anticipate the conditions under which the robot is expected to perform.*

The OSIRIS-REx target Asteroid 1999 RQ36 Bennu is ½ km in diameter and its orbit crosses the orbits of Mars and Earth.

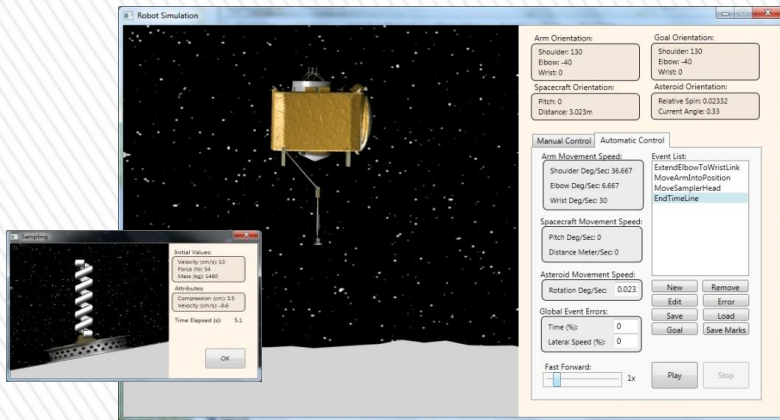


JAXA Hayabusa spacecraft

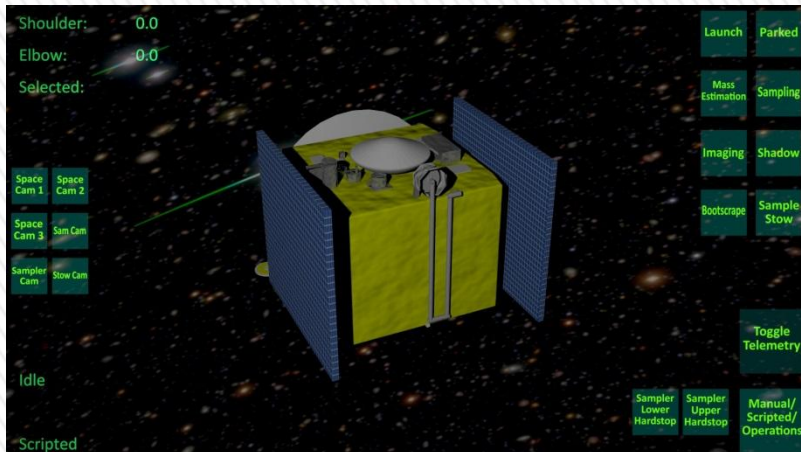
*Advisory 4:  
Search for and compare space robots flown or being planned by NASA, ESA, JAXA, the private sector, and other enterprises.*

# Visualize the Robotic Elements

**Advisory 5:** Create a visualization such as a drawing, animation, or a physical model of the robotic to understand its geometry, kinematics, and operational use.



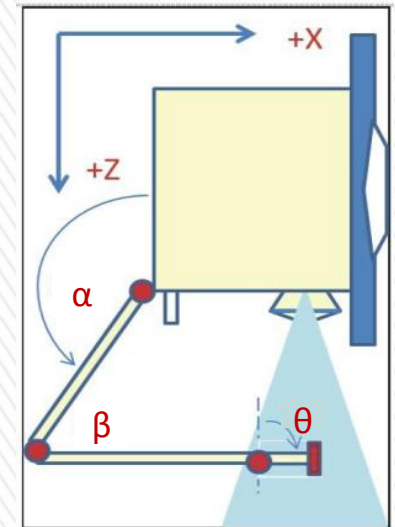
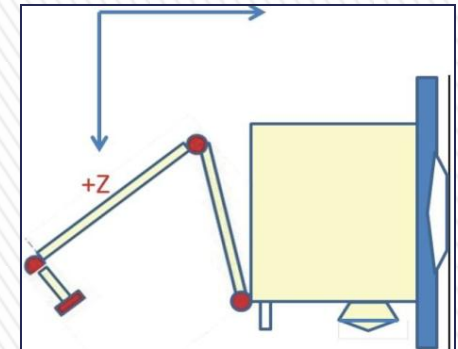
**2-D Sim with Touchdown Popup**



**3-D Simulation**

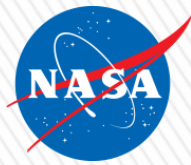


**Half-scale Model**



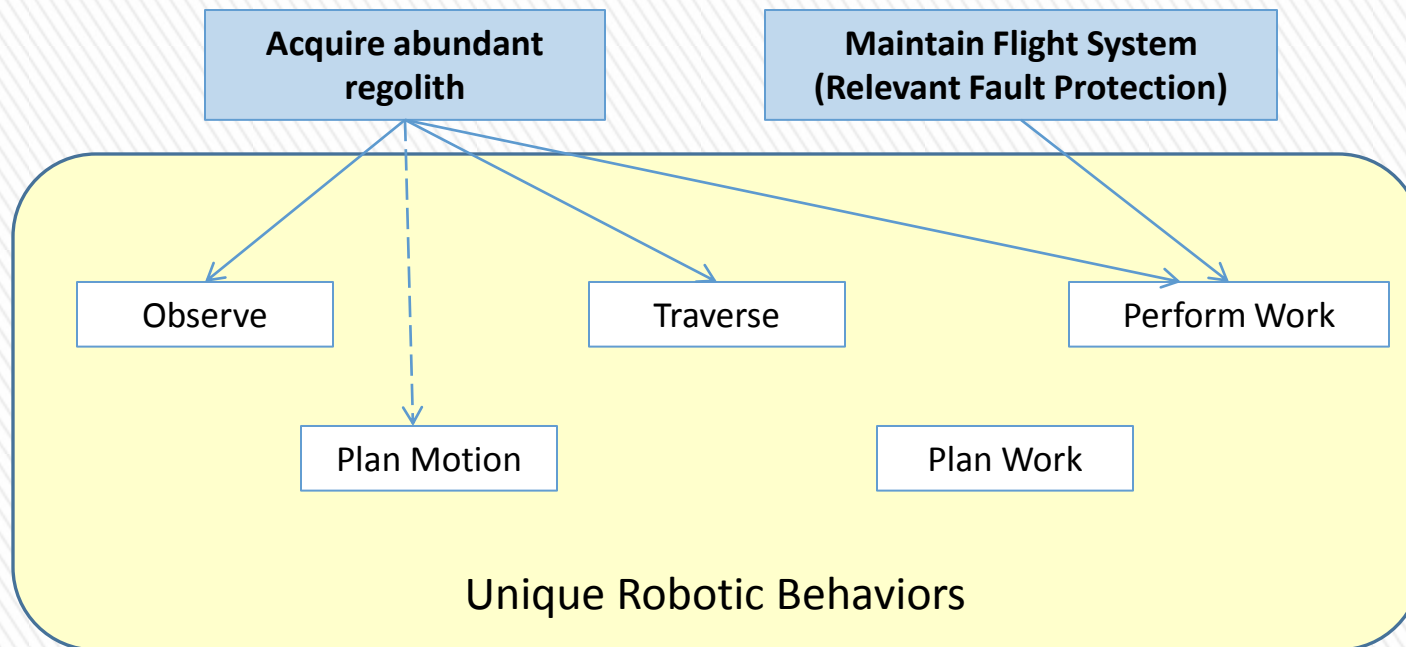
**PowerPoint Sketches**

# Map Mission Capabilities to Robotic Behaviors



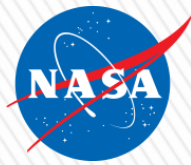
*Advisory 6: Identify how a project's robotic needs are to be satisfied by one or more of the five unique robotic behaviors early in the program development cycle.*

## OSIRIS-REx Capabilities

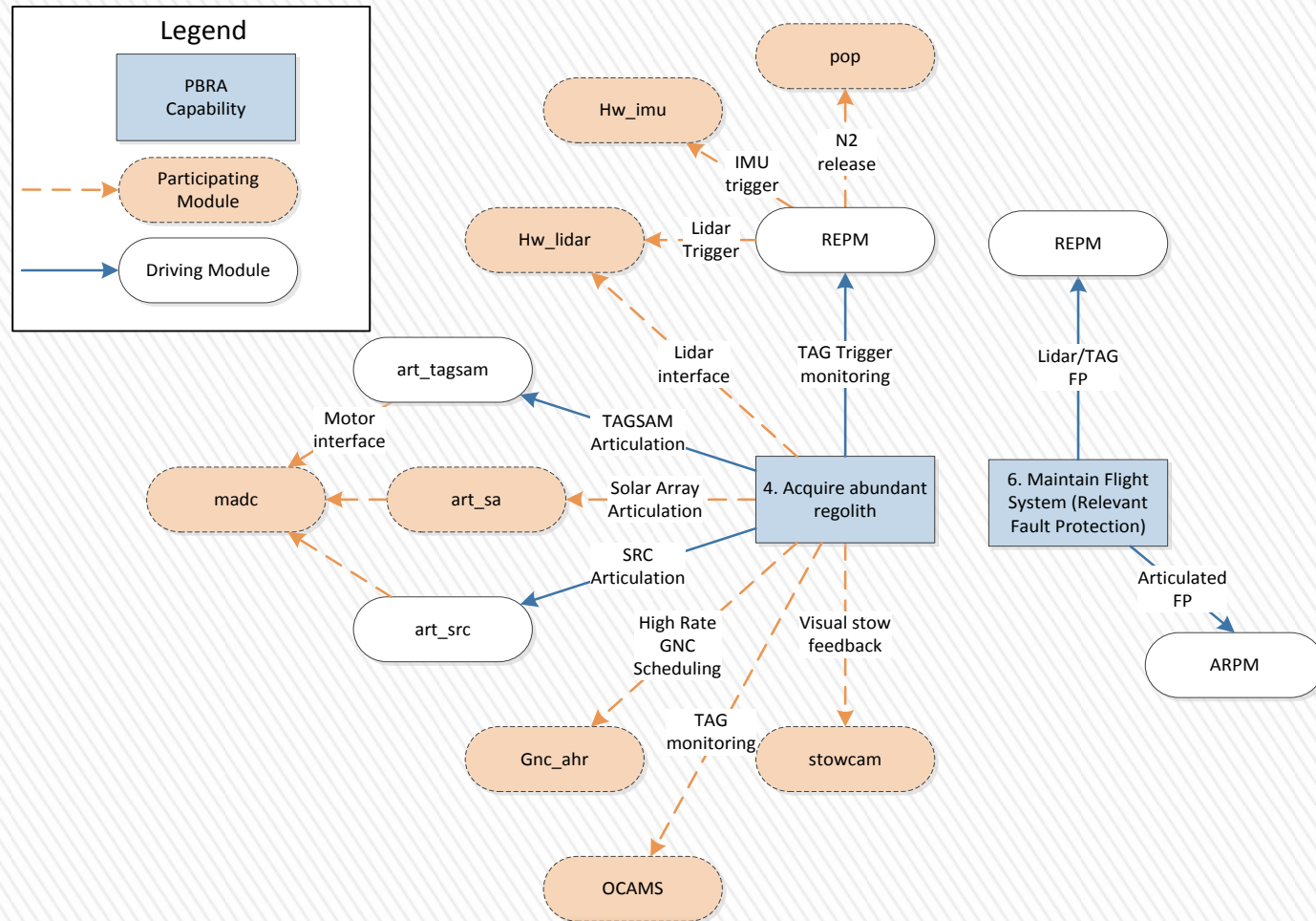




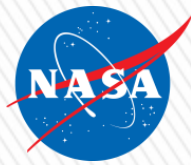
# Map Software Modules to Robotics Capabilities



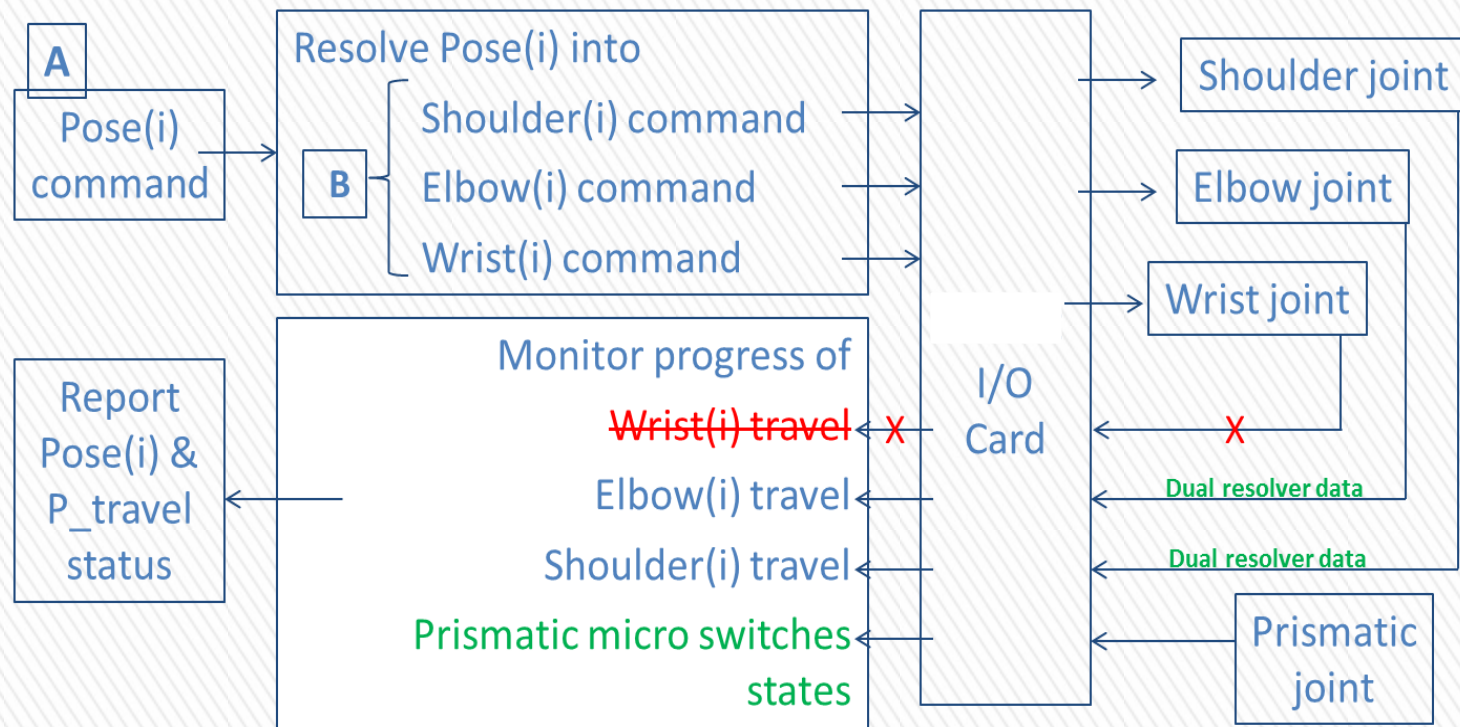
*Advisory 7: Identify relevant software modules which drive robotic capabilities and those other modules upon which the driving modules rely.*



# Model Expected Behaviors of the Robotics Modules, 1

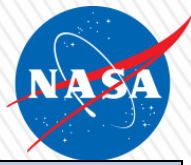


*Advisory 8: Postulate a 'best guess' at what the interfaces and signals are between the flight computer and the robotic mechanism and capture in a systems diagram. Update as more details of the program architecture become available.*



*Postulated joint command and feedback diagram with updates.*

# Model Expected Behaviors of the Robotics Modules, 2



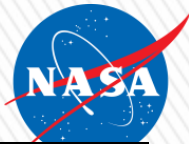
*Advisory 9: Maintain cognizance of mission milestones and the availability of new artifacts, which may refine or significantly alter the initial expected behaviors and interactions of robotics relevant software modules.*

Input		TAGSAM Mechanism	Output	
1 Stepper	→	Shoulder	→	2 potentiometers
1 Stepper	→	Elbow	→	2 potentiometers
1 Stepper	→	Wrist	→	2 discrete switches
none	→	Pogo	→	1 discrete switch
3 Pyro	→	N2 bottles	→	none
2 Pyro	→	Tube cutter	→	none
2 Pyro	→	Frangibolts	→	none

Input	Solar Array Mechanism	Output	Input	SRC Mechanism	Output
1 Stepper →	Left Pitch	→ 2 pots	1 Stepper →	Hinge motor	→ 2 discretes
1 Stepper →	Left Roll	→ 2 pots	1 Stepper →	Lid Latch(es)	→ 2 discrete
1 Stepper →	Right Pitch	→ 2 pots	None	SAM switches	→ 2 discretes
1 Stepper →	Right Roll	→ 2 pots			
6 Pyro →	Sep Bolts	→ none			

*Articulated Hardware Movement Input/Feedback Output Summary*



# Assess Robotic Systems to support PBRA

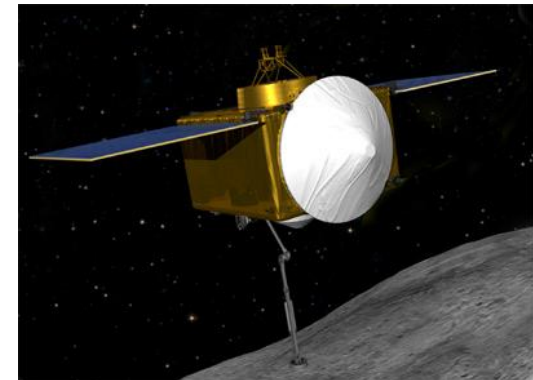
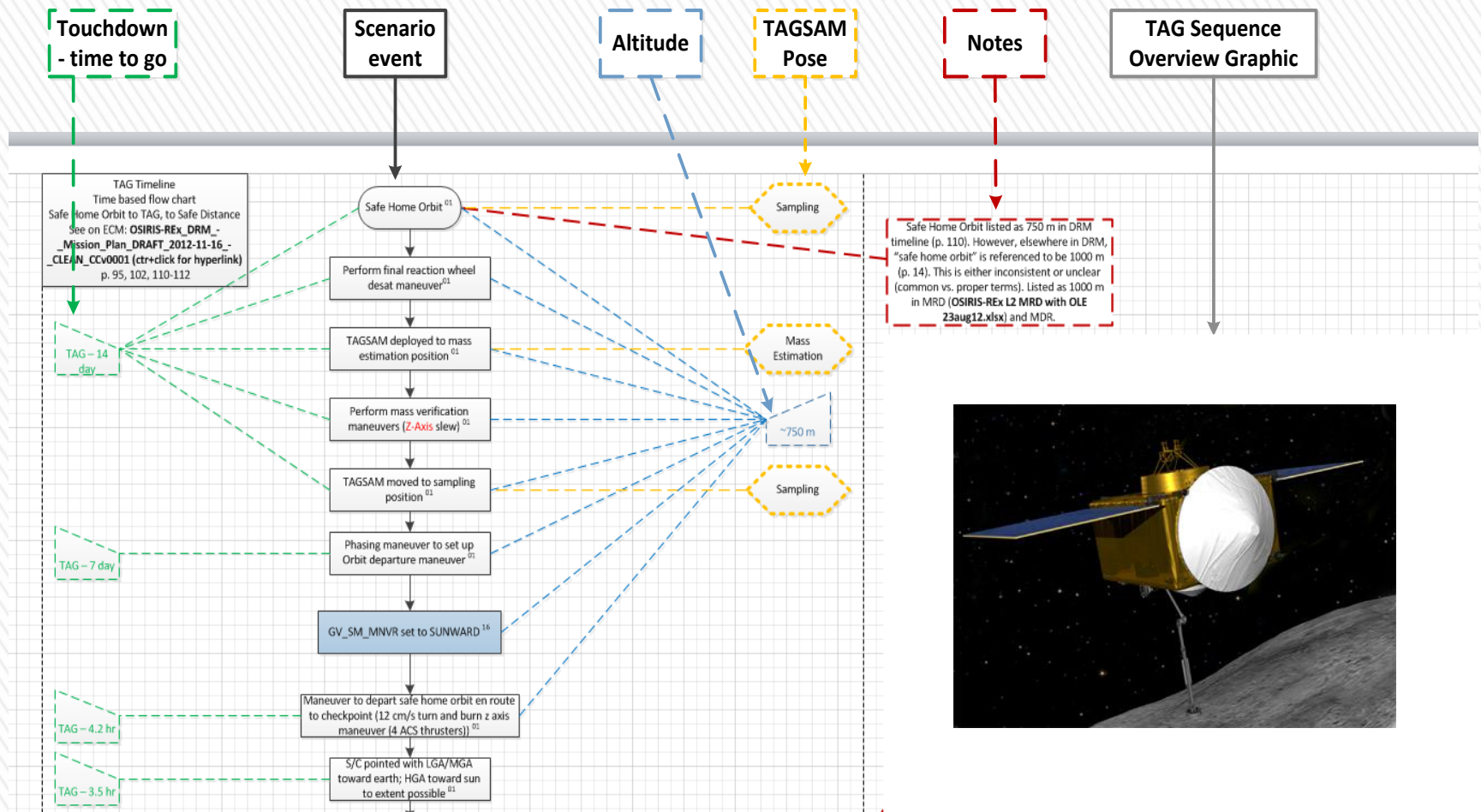
*Advisory 10: Apply the PBRA (Portfolio Risk Based Assessment) criteria to all the robotic sub-capabilities (behaviors) during the IV&V PBRA of the target mission and determine their contributions to the scoring of each criterion.*

Capability	Criteria	Recommended Changes	
		Comments	Scoring
<i>Travel to Asteroid 1999 RQ36</i>	<i>Degree of Innovation</i>	Added: very small asteroid (580 m)	1 to 2
<i>Acquire Abundant Regolith</i>	<i>Performance</i>	Clarified touch and go with more details	none
	<i>Complexity</i>	Augmented mechanical complexity and associated software	4 to 5
	<i>Development Characteristics</i>	Added: touchdown sampling has not been done before	1 to 2
<i>Return Sample Collections to Earth</i>	<i>Development Characteristics</i>	Added: sampling and return system is new	1 to 2

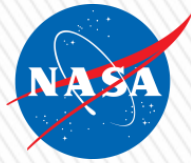


# Develop Scenarios of Robotic Events

**Advisory 11:** Create nominal and fault scenarios of expected behaviors of a robotics element to support answers to 1)what it should do, 2)should not do, and 3)will do under adverse conditions.







*Advisory 12: Postulate failure modes and consequences in preparation for analysis of the developer's fault trees.*

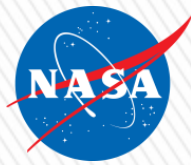
## Faults examples:

- LIDAR bias during TAG
- Power degradation during TAG and Post-TAG
- TAGSAM Joint Errors during TAG and Post-TAG

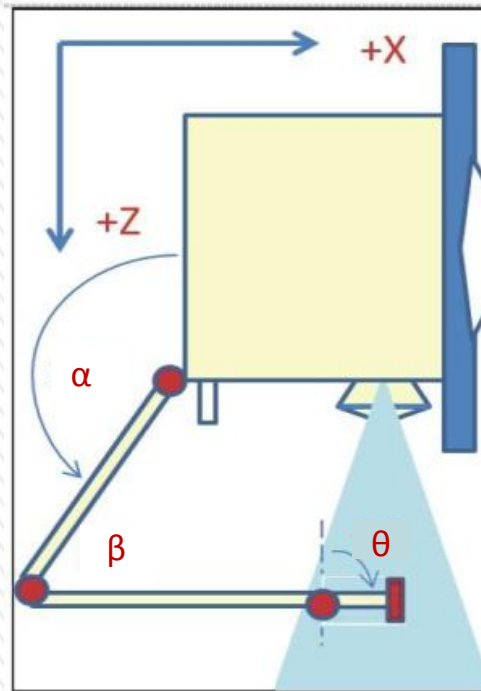
Also track 'Watch items' -- concerns/questions that you have and seek answers in future developer documentation.

Share information via a collaborative environment.

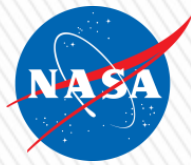
# Determine Operational Joint Positions, “arm poses”



*Advisory 13: Postulate and validate the numeric values of all poses of the robotics element and capture the information in both an event sequence table and a state space diagram.*



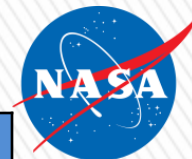
*TAGSAM posed for  
Camera inspection  
of Sampler Head*



# Understand Robot Poses, Event Sequence Table 1

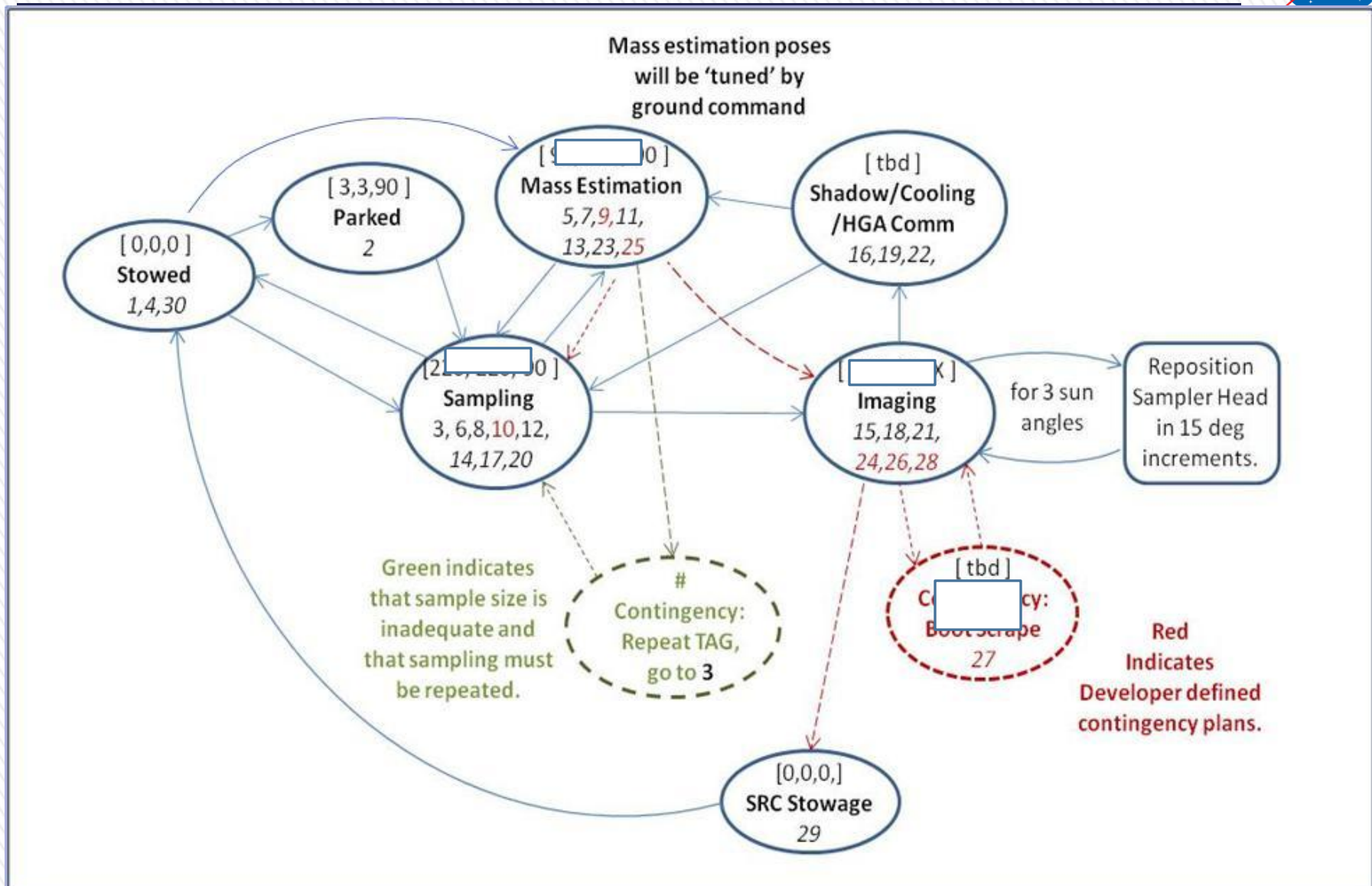
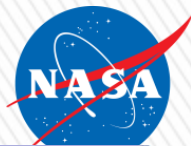
ID #	TAGSAM Pose	Phase	Shoulder (deg)	Elbow (deg)	Wrist (deg)
1	Stowed	Launch -- Approach	0	0	0
2	Parked	Approach			0
3	Sampling	Approach	2		0
4	Stowed	Approach			0
5	Mass Estimation	TAG Rehearsal # 1	9		0
6	Sampling	TAG Rehearsal # 1	2		0
7	Mass Estimation	TAG Rehearsal # 2	9		0
8	Sampling	TAG Rehearsal # 2	2		0
9	Mass Estimation (Contingency)	TAG Rehearsal # 2	9		0
10	Sampling (Contingency)	TAG Rehearsal # 2	2		0
11	Mass Estimation	TAG Rehearsal # 3	9		0
12	Sampling	TAG Rehearsal # 3	2		0
13	Mass Estimation	TAG	9		0
14	Sampling	TAG -- Post TAG	220	220	90

# Understand Robot Poses, Event Sequence Table 2



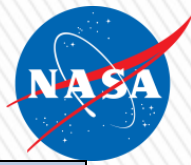
ID #	TAGSAM Pose	Phase	Shoulder (deg)	Elbow (deg)	Wrist (deg)
15	Imaging	Post TAG	148	0	0
16	Shadow/Cooling/HGA Comm	Post TAG	tbd		
17	Sampling	Post TAG	220		
18	Imaging	Post TAG	148	0	0
19	Shadow/Cooling/HGA Comm	Post TAG	tbd		
20	Sampling	Post TAG	220		
21	Imaging	Post TAG	148	0	0
22	Shadow/Cooling/HGA Comm	Post TAG	tbd		
23	Mass Estimation	Post TAG	90		
24	Imaging (Contingency)	Post TAG	148	0	0
25	Mass Estimation (Contingency)	Post TAG	90		
26	Imaging (Contingency)	Post TAG	148	0	0
27	Bootsrape (Contingency)	Post TAG	tbd		
28	Imaging (Contingency)	Post TAG	148	0	0
29	SRD Stowage	Post TAG	65		
30	Stowed	Post TAG	0	0	0
#	Contingency Repeat TAG	Post TAG	tbd	tbd	tbd

# Understand Robot Poses, State Space diagram





# Create Accessible Information



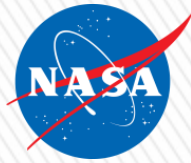
*Advisory 14: Documentation of space robotic systems as well as any other system can be hosted on a wiki to support collaborative interaction among IV&V analysts and subject matter experts.*

- Confluence wiki was created to organize and present our products to the IV&V Team.
- Some pages of the wiki were incorporated into the IV&V Team's Technical Reference

The screenshot shows a Confluence wiki page for 'Touch and Go (TAG)'. The left sidebar contains a navigation menu with categories like 'Internal', 'Project Support', 'MSL', 'OSIRIS-REx', 'Additional Support', 'Facilitated Discussion', 'Hayabusa', 'Touch and Go (TAG)', 'Cameras', 'Lidar Data During TAG', 'TAG Contact Triggers', 'TAG Faults', 'TAGSAM', 'TAGSAM Poses', 'TAG Scenarios', and '1. TAG Scenario' and '2. Post-TAG Scenario'. The main content area has a header 'Touch and Go (TAG)' with a small image of a robot. Below the header, it says 'Added by Ricky Forquer, last edited by David Turner on May 03, 2013 (view change)'. A red warning box states: 'This page is part of the OSIRIS-REx Technical Reference. Moving the page or altering the title will break the link on ECM.' Below this is a 'Table of Contents' section with links to 'Overview', 'TAG Pages' (which includes 'TAG Scenarios', 'TAGSAM', 'TAG Contact Triggers', 'Cameras', 'TAG Faults', and 'Lidar Data During TAG'), and 'References'. The 'Overview' section is partially visible at the bottom.

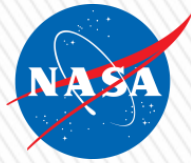
# Potential Future Robotics Missions

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- Asteroid redirection mission
- MARS 2020 rover
- Satellite servicing at geosynch orbit
- Robonaut

The Robotics Guide is applicable to all of these missions with some augmentation required in vision-derived geometry and constrained motion control.



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Comments/Questions?