Space Shuttle Program Dual Docked Operations

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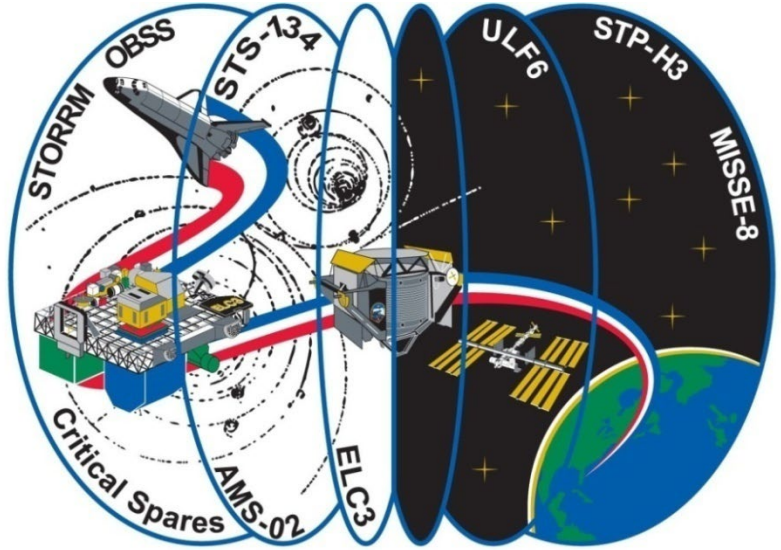


What Is Dual Docked Operations (DDO)?

- DDO is the docking or undocking of a Russian Vehicle (RV) during Space Shuttle Orbiter/International Space Station (ISS) mated operations.
- This paper and presentation summarizes the concept definition, studies, and analysis results generated by the Space Shuttle Program (SSP), ISS Program (ISSP), and Mission Operations Directorate for implementing DDO during mated Orbiter/ISS missions. [1]
- Due to the ever-increasing visiting vehicle traffic to and from the ISS, it became apparent to both the ISSP and the SSP that there would arise occasions where conflicts between a visiting vehicle docking and/or undocking could overlap with a planned Space Shuttle launch and/or during mated Orbiter/ISS operations.
- This potential conflict provided the genesis for evaluating risk mitigations to gain maximum flexibility for managing potential visiting vehicle traffic to and from the ISS and to maximize launch and landing opportunities for all visiting vehicles.
- Reviews were conducted to assess the viability and readiness of the SSP to protect for DDO on any given mission and it was found to be technically feasible

[1] Sills, J. W., and Bruno, E. E., "Space Shuttle Program (SSP) Dual Docked Operations (DDO)," NASA TM-2016-219350.

STS-134 & Soyuz Fly-about Summary

- Dual Docked Operations generic assessments completed in Summer 2010
- Mission specific analysis for non-generically cleared technical disciplines completed for Soyuz Fly-about during STS-134
  - Normal planned assessments based on updated attitude timelines

		Analysis Performed	
Area Of Emphasis	Impacted By DDO	Mission Specific	Generic
Flight Operations and Integration			
Loads and Dynamics JTWG	Yes	✔	
Flight Control Structures WG	Yes	✔	
C&T Panel	Yes		✔
Vehicle Configuration	Yes		✔
ECLSS JTWG	No		✔
Power/Avionics JTWG	No		✔
Cargo On-orbit Loads	Yes		✔
Cargo Thermal Control	Yes	✔	
Cargo EME	Yes		✔
Cargo Integration Hardware	Yes		✔
Cargo Reconfiguration Eng.	No		✔
Cargo Safety and Reliability	No		✔
Cargo Avionics	No		✔
OMRSD	No		✔

		Analysis Performed	
Area Of Emphasis	Impacted By DDO	Mission Specific	Generic
Orbiter Project Office			
Windows	Yes	✔	
Cameras	Yes		✔
OBSS Sensors	Yes	✔	✔
RMS	Yes		✔
Trajectory Control Sensor	Yes		✔
Orbiter Loads (ODS)	Yes	✔	✔
TPS	Yes		✔
RCC	Yes		✔
PLBD and Radiators	Yes		✔
Star Trackers	Yes		✔
Ku Antenna	Yes		✔
TCS - Passive Thermal Control System	Yes	✔	✔
Toxicology - Payload Bay	Yes		✔
RFI/EMI	Yes		✔
IGNC	Yes	✔	

STS-134 Mission Specific Assessments for Soyuz Fly-about

- ✓ SSP/ISS mated Soyuz dynamic un-dock and docking loads analysis - Complete
  - ✓ Overall peak loads (docking and undocking) at Orbiter/ISS interface: ~ 40% limit
  - ✓ Soyuz thruster firing test loads are bounded by Russian Segment Maneuver loads (~6% of limit at Orbiter/ISS interface)

- ✓ Communications & Tracking- Complete
  - ✓ Evaluated generically and no issues between Soyuz to Shuttle Radio Frequency Compatibility
  - ✓ For STS-134, MOD/Shuttle will mode Shuttle Ku to standby during the Soyuz fly-about unless needed by ISS

- ✓ On Orbit Integrated Guidance Navigation & Control analysis – Contingency Vernier Reaction Control System (VRCS) control analysis – Complete
  - ✓ Evaluated for STS-133: VRCS capable of maneuvers and holds except for Orbiter Mated Control during the Soyuz re-docking

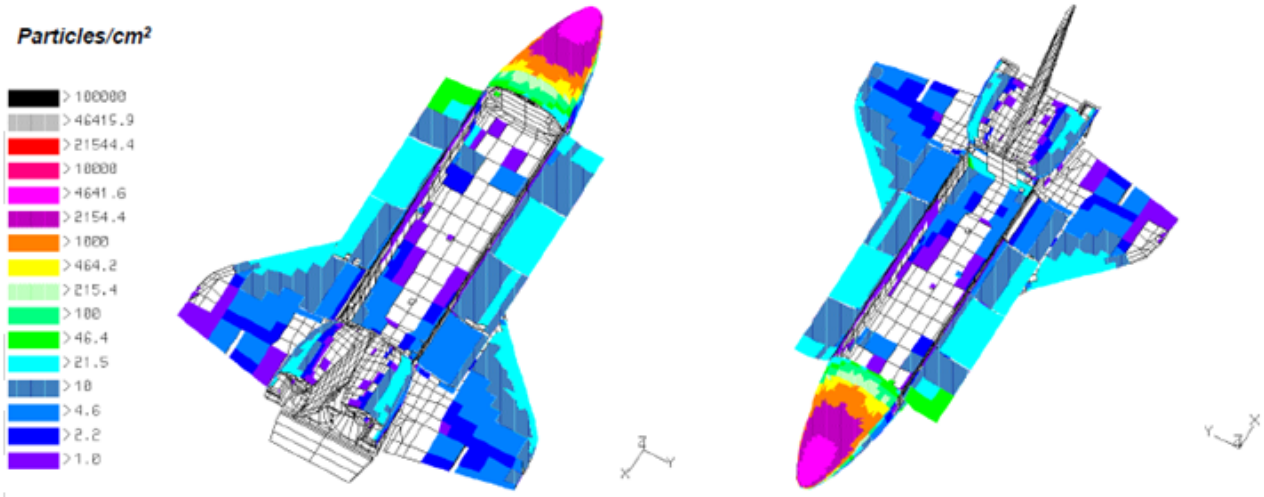
- ✓ Thermal analysis – Complete
  - ✓ No Orbiter passive thermal issues
    - ✓ Orbiter has an “any attitude” capability of 3 to 5 hours depending on beta
    - ✓ The attitude timeline was continuously screened to assure no Orbiter thermal constraints were violated
  - ✓ OBSS was stowed on ISS given current operational timeline scenario

STS-134 Mission Specific Assessments for Soyuz Fly-about

- ✓ Contamination assessment - Complete
  - ✓ Orbiter Boom Sensing System (OBSS)/sensor packages position will be in handoff (undock) position for Soyuz Thruster testing
  - ✓ For Fly-about, OBSS/sensor packages will be stowed on ISS
  - ✓ Trajectory Control System, payload bay cameras, and Orbiter arm cameras will be sufficiently shielded from, and/or pointed away from, the Soyuz plume environment
  - ✓ Star Tracker doors closed

Example particle fluence results for MRM2 zenith Russian vehicle proximity operations

Only Orbiter shown



1-5 micron particles

Russian Vehicle Approach to MRM2 Zenith, 8S-Based History

In MRM2 zenith case, from available jet firing histories the 8S (Soyuz) mission approach firings produce among the highest Orbiter surfaces particle fluence and contamination estimates.

- ✓ **Post-flight contamination assessment**
  - ✓ Johnson Space Center Toxicology and Kennedy Space Center ground personnel reviewed possible deposition to determine level of post-flight sampling and assessment
    - ✓ Levels were found to be less than one angstrom after landing

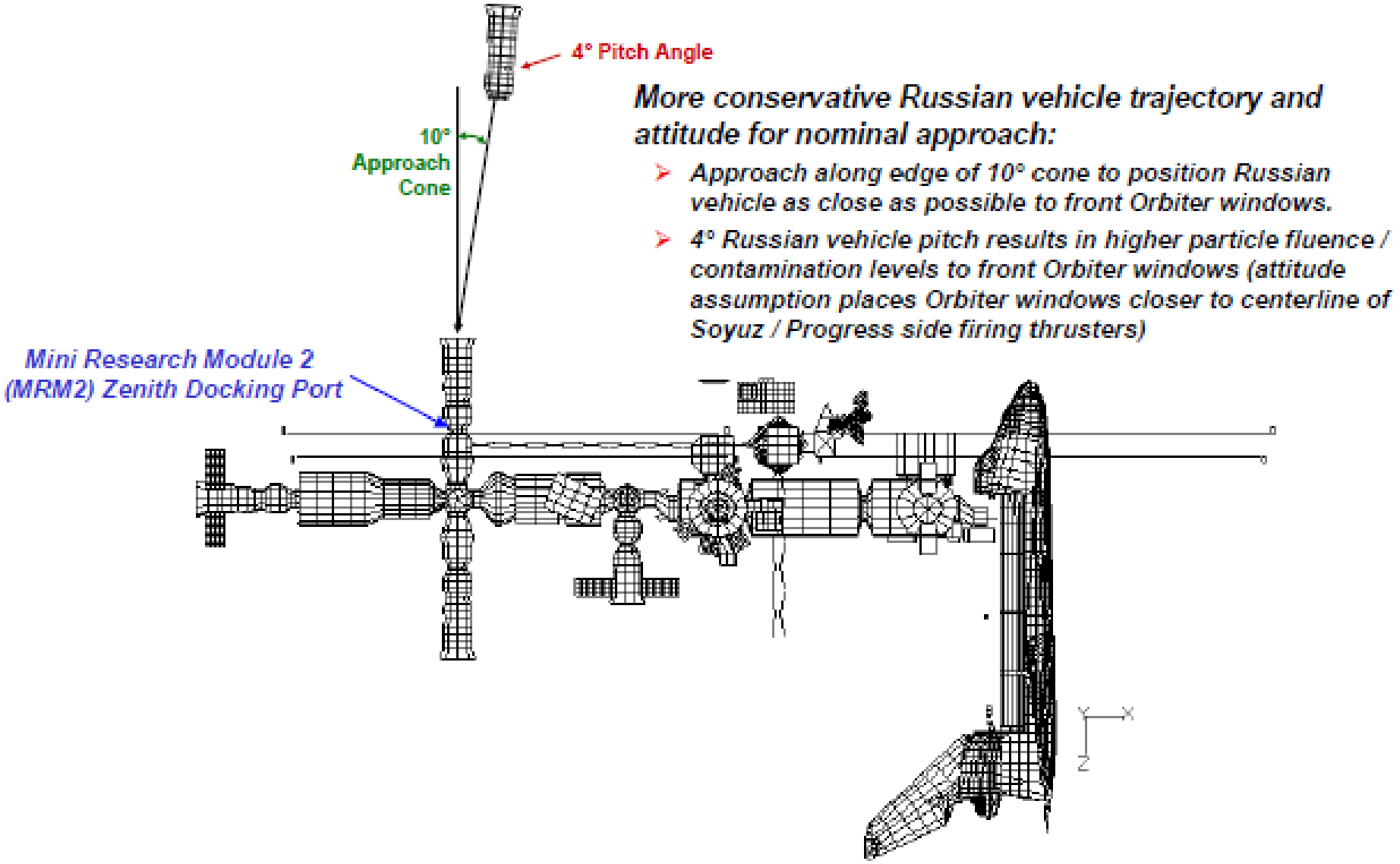
STS-134 Mission Specific Assessments for Soyuz Fly-about

✓Soyuz Plume Fluence - Complete

- ISS defined STS-134 mission specific fluence data as 2 times “Bounded” nominal docking
  - Envelopes both an undock and docking of a Russian Vehicle in manual mode
  - Conservatively bounds and protects for Russian Segment 10 deg specification approach cone and for crew piloting uncertainties
    - ~2 x 5000 particles/cm2 (from Bounded Nominal Approach case) = 10,000 particles/cm2

- Orbiter Windows Problem Resolution Team position
  - Mission specific environment represents no increase in risk to the mission
  - Previous window specimens tested did not violate certification strength
  - Negligible sensitivity of strength to the fluence range tested
  - An increase in fluence is not expected to have a detrimental effect on strength for entry

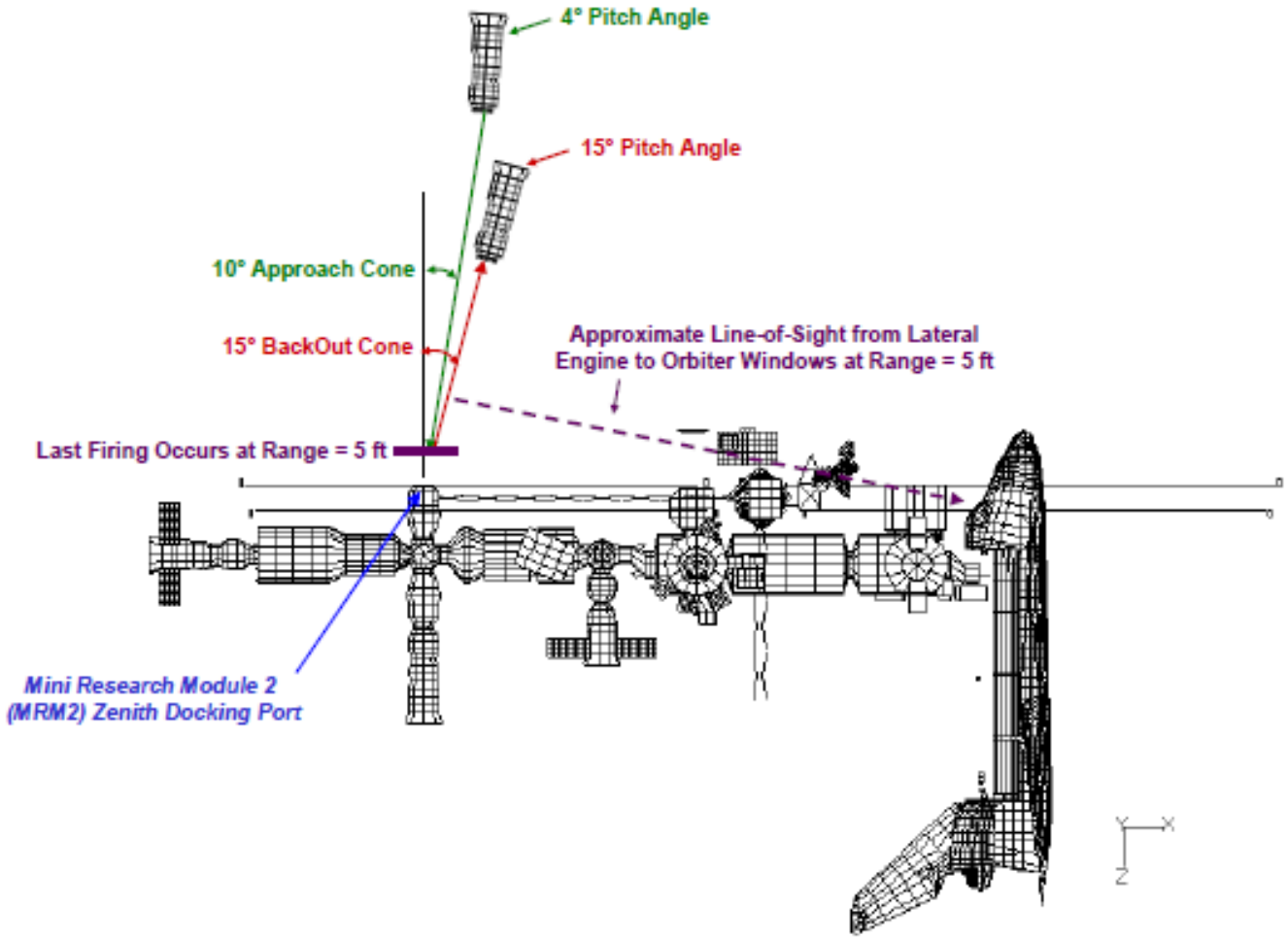
Russian Vehicle Trajectory and Attitude for Nominal Approach to Mini Research Module (MRM2)



More conservative Russian vehicle trajectory and attitude for nominal approach:

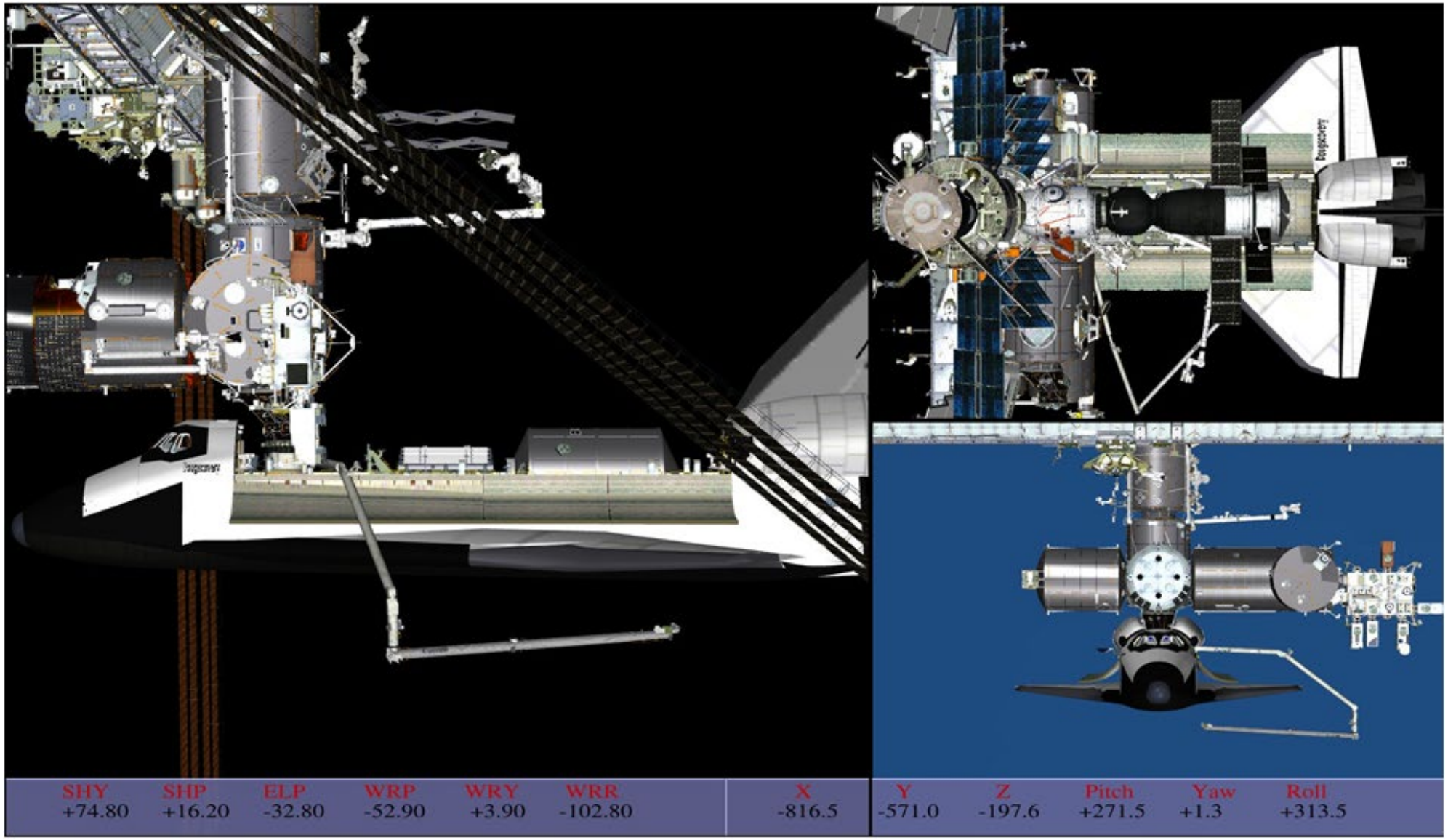
- *Approach along edge of 10° cone to position Russian vehicle as close as possible to front Orbiter windows.*
- *4° Russian vehicle pitch results in higher particle fluence / contamination levels to front Orbiter windows (attitude assumption places Orbiter windows closer to centerline of Soyuz / Progress side firing thrusters)*

Russian Vehicle (RV) Trajectory and Attitude for Synthesized MRM2 Abort



- ISS has no abort data from the Russian Space Agency, ISS synthesized data based on nominal thruster firings and RV abort specifications for MRM2/Zenith port case.
  - 15 deg back-out cone, 15 deg max pitch angle with mid thrusters always pointed at windows

OBSS Sensor Protect Position For Soyuz Fly-about



For STS-134, the HII Transfer Vehicle was not present

STS-134 Endeavour Docked to ISS as viewed from Soyuz

FD 8: iss027e036679 (May 23, 2011) ---- One of first legacy photos taken from Soyuz TMA-20 of a Shuttle (Endeavour, left of center) docked to ISS.

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  - Johnson Space Center (JSC) S&MA - Brian Rochon
  - JSC Proximity Operations Environments - Quyen Jones

- The overarching goal of this effort was to assess the viability and readiness of the SSP to protect for DDO on any given mission.
- Results represent a generic assessment of the SSP and ISSP integrated safety and technical evaluations of DDO and provides mission-specific and operational analyses realized on STS-134.