HST SM4 Review

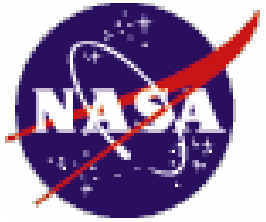
JSC Mission Operations Directorate

Flight Director Office

DA8/A. Ceccacci

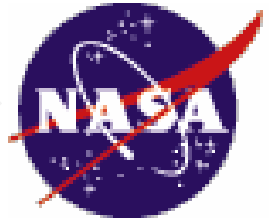
October 2, 2006

Overview



- **MOD assessment in support of HST SM4.**
- **The following items have been drafted/evaluated:**
  - **Mission Priorities**
  - **TPS Inspections**
  - **Draft SM4 Overview Timeline (11 Day Mission)**
  - **Possible Timeline Threats**
  - **Contingency Timeline Scenarios**
  - **Orbiter Attitude Timeline and MMOD Risk Reduction Options**
  - **LON Support**

Mission Priorities (DRAFT)



- TPS inspections (FD2, Focused, Late)
- Rendezvous/Grapple.
- SM4 Tasks (top 10 as defined in PIP CR P14009-0262/HST SM4 Requirements)
  - RSUs (3)
  - Battery Modules (2)
  - Cosmic Origins Spectrograph (COS)
  - Wide Field Camera (WFC)
  - Fine Guidance Sensor 3 (FGS 3) & Optical Control Electronics Enhancement Kit (OCE-EK)
  - NOBL Bay 8
  - NOBL Bay 5
  - STIS Repair
  - NOBL Bay 7
  - Install Soft Capture Mechanism TBD

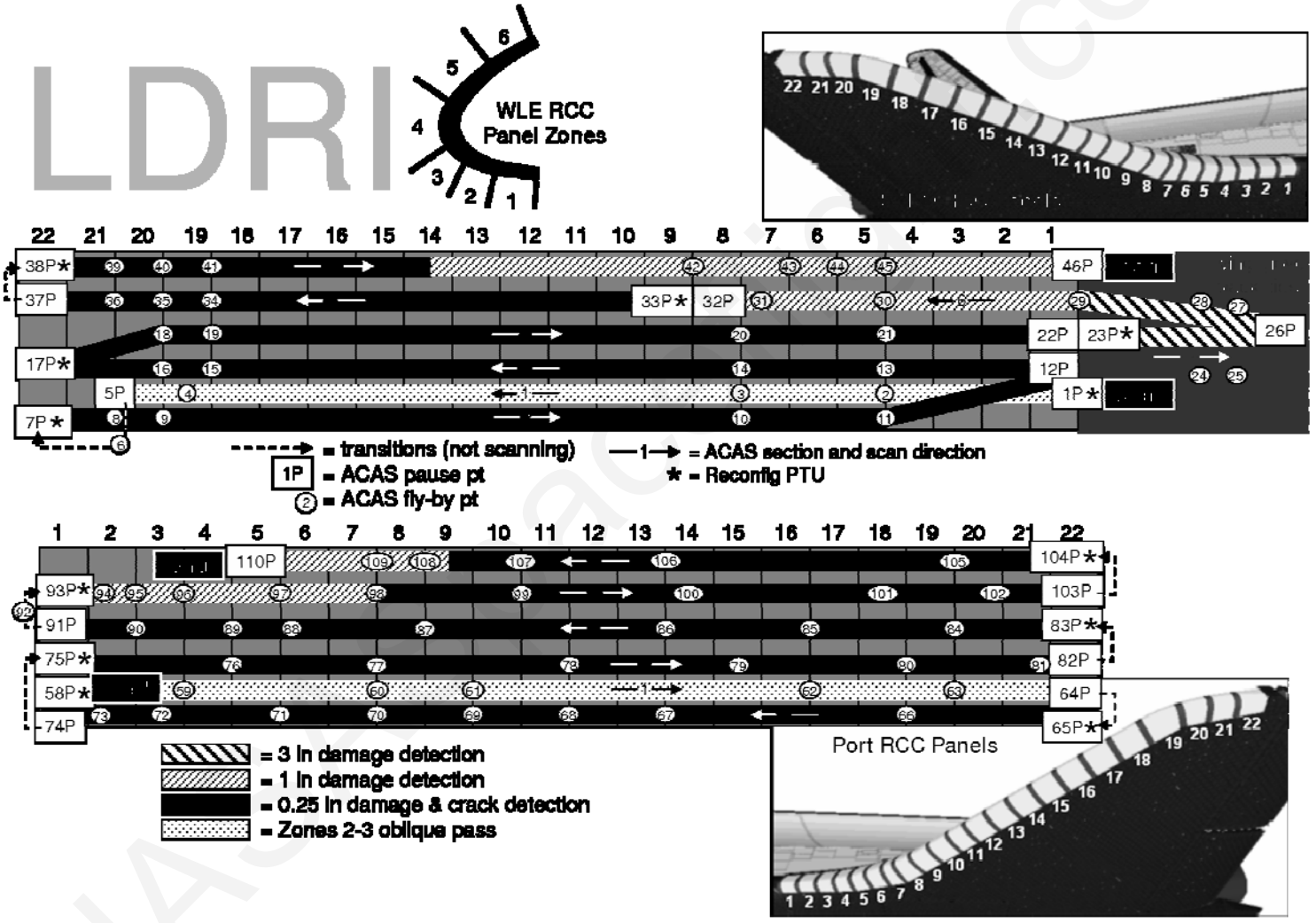
*** EVA timeline driven by task duration/EVA time available not necessarily priority.**

TPS Inspections

- **TPS Inspections <u>can</u> be accomplished.**
  - **Utilize Current LDRI Survey (STBD WLE, Nose Cap, Port WLE) for FD2 RCC inspection and Late Inspection for MMOD.**
  - **Utilize ITVC Tile Acreage (belly) Survey developed prior to STS-114.**
    - » **Contingency Tile acreage inspection if RPM/RPM photos (from ISS) could not be accomplished.**
    - » **ITVC Tile Acreage Survey Coverage Analysis (8/10/06) performed by ER7 showed that the current survey does not provide full damage detection resolution coverage for entire tile acreage.**
      - **Update of the procedure required to support required damage criteria detection.**
      - **"TBD" increase in time required to execute.**
        - **Draft timeline assumes 'current tile acreage procedure" execution time and allows entire TPS (RCC and Tile acreage) survey to be accomplished on FD2.**
        - **May require additional time on FD3 to complete**
  - **Focused Inspection (RCC/Tile) as required.**

HOOK
VELCRO

OBSS LDRI SCAN PATTERN CUE CARD – STBD & PORT



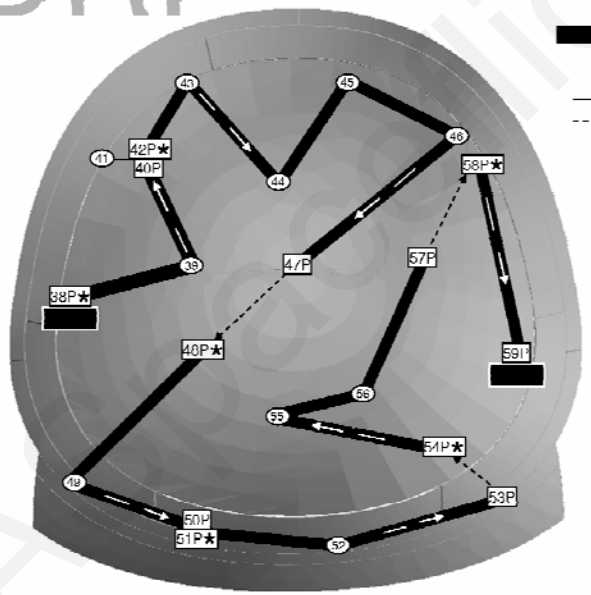
PDRS-10a/121/O/B

TOP
Back of 'OBSS LDRI SCAN PATTERN CUE CARD – DOCKED STBD

HOOK
VELCRO

OBSS LDRI SCAN PATTERN CUE CARD – DOCKED NOSE CAP

LDRI

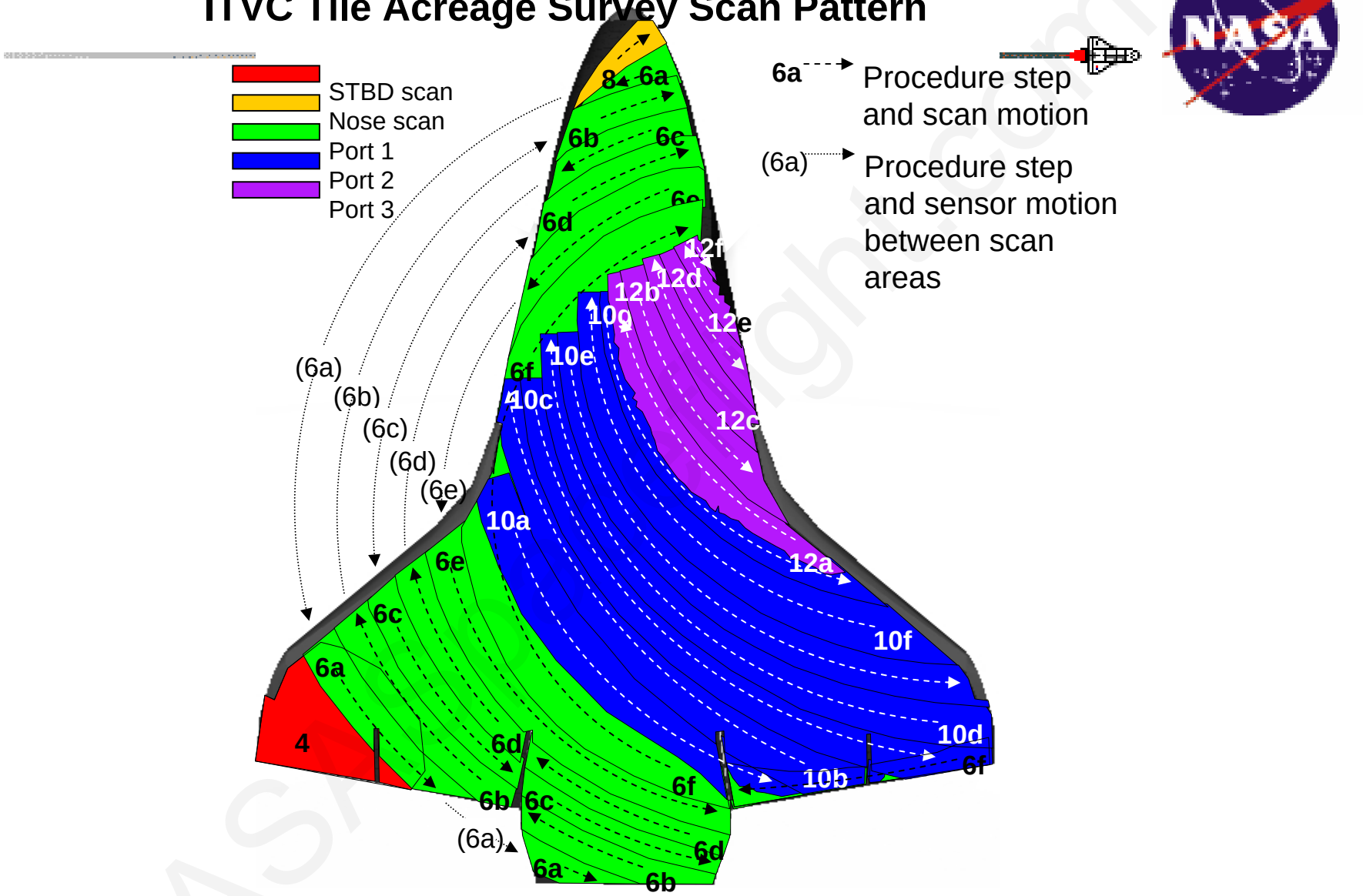


= 0.25 in damage criteria
1P = ACAS pause pt
2 = ACAS fly-by pt
1 = ACAS section & scan direction
= non-scan transitions
★ = Reconfig PTU

PDRS-15b/121/C/A

Rev: 6/2/05

ITVC Tile Acreage Survey Scan Pattern



Approximately to scale. Do not use to quantify scan footprint overlap
Footprint estimates based on DOUG analysis using 45 deg surface incidence angle and ITVC HFOV = 20.0 deg RCC Excluded

Mission Timeline Overview

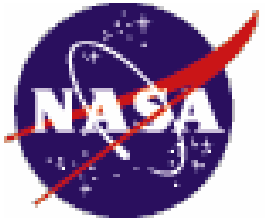
SM4 Mission Draft Timeline (11* Days)

FD1	FD2	FD3	FD4	FD5	FD6	FD7
•Ascent •PI •RMS C/O	•TPS Surveys (RCC & Tile Acreage)	•RNDZ •HST Berth	•HST EVA #1	•HST EVA #2	•HST EVA #3	•HST EVA #4

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•HST EVA #5	•HST Release •OBSS Unberth •Late Inspection Part I (STBD WLE & Nose Cap)	•Late Inspection Part II (Port WLE) •OBSS Berth •Crew Off Duty	•EOM-1 •(Cabin Stow, FCS C/O, RCS Hot Fire, etc.) •Crew Off Duty	•Entry	•EOM +1	•EOM +2

***11 Day capability based on STS-109 predicted power usage.**
Expect STS-125 power requirements to be similar.

Possible Timeline Threats



- **Focused Inspection (OBSS Berth/Unberth and # of Areas of Interests.)**
  - RMS utilized for all EVAs
  - Need to determine if Focused Inspection can be a accommodated pre/post EVA (crew resources, orbiter flight deck/middeck real estate, SCSC, maintaining activity oversite, etc.) to minimize timeline impact.
    - » May require deletion of an EVA (if Late Inspection retained)
- **Tile Acreage Survey**
  - Additional time requirements to meet required damage detection resolution (as mentioned on chart 4).
    - » May require time on FD3 (post HST grapple/berth) to complete.
- **HST Battery Charge Requirements post-grapple (1 REV).**
  - Predicted Battery capabilities (capacity) at 9/08 would require this.

Contingency Timeline Scenarios Review

Mission Day required for Focused Inspection

FD1	FD2	FD3	FD4	FD5	FD6	FD7
•Ascent •PI •RMS C/O	•TPS Surveys (RCC & Tile Acreage)	•RNDZ •HST Berth	•HST EVA #1	•Focused Inspection (OBSS Unberth, FI, OBSS Berth)	•HST EVA #2	•HST EVA #3

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•HST EVA #4	•HST Release •OBSS Unberth •Late Inspection Part I (STBD WLE & Nose Cap)	•Late Inspection Part II (Port WLE) •OBSS Berth •Crew Off Duty	•EOM-1 •(Cabin Stow, FCS C/O, RCS Hot Fire, etc.) •Crew Off Duty	•Entry	•EOM +1	•EOM +2

- •Focused Inspection activities added to FD5
  - •Worst case assumption that FI activities can not be run in parallel with EVA prep activities.
- •RCC and Tile acreage Imagery review not completed until pre-sleep FD3.
  - •FI procedure development FN3 and FD4
    - •If procedure development completed earlier, possible option to swap FI Day with HST EVA #1.
- •HST EVA #5 deleted
- •Late Inspection for MMOD and EOM +2 capability retained.

Focused Inspection & Repair w/ Late Inspection)

FD1	FD2	FD3	FD4	FD5	FD6	FD7
•Ascent •PI •RMS C/O	•TPS Surveys (RCC & Tile Acreage)	•RNDZ •HST Berth	•HST EVA #1	•Focused Inspection (OBSS Unberth, FI, OBSS Berth)	•HST EVA #2	•TPS Repair EVA Prep and procedure review.

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•TPS Repair EVA	•HST Release •OBSS Unberth •Late Inspection Part I (STBD WLE & Nose Cap)	•Late Inspection Part II (Port WLE) •OBSS Berth •Crew Off Duty	•EOM-1 •(Cabin Stow, FCS C/O, RCS Hot Fire, etc.) •Crew Off Duty	•Entry	•EOM +1	•EOM +2

- •Focused Inspection activities added to FD5
  - •Worst case assumption that FI activities can not be run in parallel with EVA prep activities.
- •RCC and Tile acreage Imagery review not completed until pre-sleep FD3.
  - •FI procedure development FN3 and FD4
    - •If procedure development completed earlier, possible option to swap FI Day with HST EVA #1.
- •HST EVA #3, #4 and #5 deleted
- •Late Inspection for MMOD and EOM +2 capability retained.

Focused Inspection & Repair (w/o Late Inspection)

FD1	FD2	FD3	FD4	FD5	FD6	FD7
•Ascent •PI •RMS C/O	•TPS Surveys (RCC & Tile Acreage)	•RNDZ •HST Berth	•HST EVA #1	•Focused Inspection (OBSS Unberth, FI, OBSS Berth)	•HST EVA #2	•TPS Repair EVA Prep and procedure review.

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•TPS Repair EVA	•HST EVA #3	•HST Release •Crew Off Duty	•EOM-1 •(Cabin Stow, FCS C/O, RCS Hot Fire, etc.) •Crew Off Duty	•Entry	•EOM +1	•EOM +2

- •Focused Inspection activities added to FD5
  - •Worst case assumption that FI activities can not be run in parallel with EVA prep activities.
- •RCC and Tile acreage Imagery review not completed until pre-sleep FD3.
  - •FI procedure development FN3 and FD4
    - •If procedure development completed earlier, possible option to swap FI Day with HST EVA #1.
- •HST EVA #4 & #5 deleted. Back to Back EVAs for EV1
- •Late Inspection for MMOD removed to support TPS repair & HST Servicing objectives. EOM+2 retained.

Late Inspection/MMOD Repair Timeline

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•HST EVA #5 (or HST EVA #4 if FI required on FD5)	•HST Release •OBSS Unberth •Late Inspection Part I (STBD WLE & Nose Cap)	•Late Inspection Part II (Port WLE) •OBSS Berth •Crew Off Duty *•Procedure development initiated as soon as damage identified.* *•RMS or RMS/OBSS (dependent on damage location), crack/plug (dependent on damage extent)*	•EOM-1 (Cabin Stow, FCS C/O, RCS Hot Fire, etc.) *•Procedure development validation.* *•RCC Repair EVA prep (Tools, materials, RMS/OBSS activities, etc.)*	•Entry *•RCC Repair EVA* *•EOM-1 (Cabin Stow, FCS C/O, RCS Hot Fire, etc.)*	•EOM +1 *•Entry*	•EOM +2 *•EOM +1*

- Timeline deltas in *RED/Italics*
- Crew is trained for RCC repair.
- Procedure development will focus on RMS/OBSS location and making generic repair procedure specific to damaged area.
- Damage identification will not be known until post crew sleep on FD9 (STBD WLE/Nosecap) or pre-sleep FD10 (Port WLE) based on imagery review process.
- Timeline does not include additional focused inspection of repaired area.
- 24 hour NOAX cure time (versus 48).
- Still protects a Systems/WX Waveoff day.

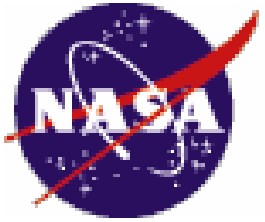
HST Contingency EVA (additional option)

FD1	FD2	FD3	FD4	FD5	FD6	FD7
•Ascent •PI •RMS C/O	•TPS Surveys (RCC & Tile Acreage)	•RNDZ •HST Berth	•HST EVA #1	•HST EVA #2	•HST EVA #3	•HST EVA #4

FD8	FD9	FD10	FD11	FD12	FD13	FD14
•HST EVA #5	•HST Contingency EVA •HST Release if EVA < 4 hours	•HST Release (if not performed on FD9) •Or/Reduced Late Inspection (2-3 hours total operations). •Crew Off Duty	•EOM-1 •(Cabin Stow, FCS C/O, RCS Hot Fire, etc.) •Crew Off Duty	•Entry	•EOM +1	•EOM +2

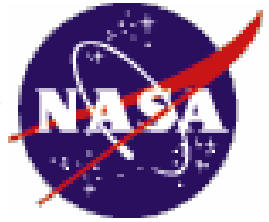
Orbiter Attitude Timeline and MMOD Risk Reduction Options

MMOD Risk Reduction



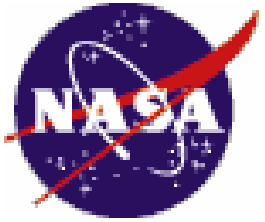
- **Used "MMOD" spreadsheet (provided by KX) to evaluate additional attitude/operational options to reduce the MMOD debris hit probability.**
  - **KX would have to validate/verify assessment.**
- **Additional analysis (Orbiter/HST thermal, cryo/power, prop usage, EOM mission landing opportunities, HST SAW capabilities, etc.) would be required to determine actual operational feasibility.**

MMOD Risk Reduction



- **Nominal Timeline Assumptions**
  - **FD2 Inspection and Late Inspection**
  - **180 hrs of –ZLV-XVV (~ 85 hrs pre/post HST and 100 hours of HST ops)**
  - **10 hours EOM thermal conditioning (-ZLV-YVV)**
  - **12 hrs Battery Charging**
  - **16 hours Inertial for FD2 and Late Inspections**
  - **16 hrs HST Sun Protection**
  - **18 hrs for Post Insertion, Rndz, capture, reboost, release, deorbit prep**
  - **Last Inspection effectiveness EOM -70 hrs**
  - **Late Inspection Detection Level ¼ inch**

MMOD Risk Reduction



- **Possible MMOD Risk Reduction Options**
  - **Modified H2O Dump attitudes (30 deg aft radial down versus -ZLV Nose South/retrograde)**
    - » Pros
      - Same recontact protection, Better Ku Comm
    - » Cons
      - None
  - **Updated Inertial Attitude for Scheduled Inspections (FD2 and Late)**
    - » Pros
      - Prop savings
    - » Cons
      - Loss of consistent lighting, Poor Ku Comm for Inspection (better in +ZLV)
  - **Updated Battery Charge Attitude (if HST SAW pointing can accommodate)**
    - » Pros
      - Prop savings
    - » Cons
      - HST SAW Slew required, Poor Ku comm.
  - **Biased –ZLV-XVV while HST berthed (20 deg pitch bias)**
    - » Pros
      - Same thermal environment as unbiased –ZLV, 2nd best MMOD attitude.
    - » Cons
      - More Aft Prop usage due to pitch bias.

MMOD Risk Reduction

- **Possible MMOD Risk Reduction Options (cont)**
  - **+ZLV-XVV**
    - » Pros
      - Best MMOD attitude, very good Ku comm, no additional prop usage, Excellent star acquisition.
    - » Cons
      - PLB thermal environment impacts (cold) for HST ORU's pre/post capture, additional cryo usage due to cold environment, possible EOM bondline and tire thermal impacts, Loss of earth view.
  - **Orbit Adjust prior to Late Inspection**
    - » Perigee Adjust - equivalent circular orbit ~ 210 NM

MMOD Risk Reduction

Timeline Option (A)	MMOD Probabilities (B)
•Nominal Timeline (No Inspections)	1/122
•Nominal Timeline (FD2 Inspection Only)	1/124
•Nominal Timeline (FD2 and Late Inspection)	1/186 With OA 1/240
•Nominal Timeline (FD2 and Late Inspection) but remove a mission day	1/197 With OA 1/260
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O Dump attitude (7 hrs)	1/187 With OA 1/241
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O dump attitude, -ZLV-XVV for inspections (both FD2 and Late), no EOM Mission thermal.	1/192 With OA 1/245
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O dump attitude, -ZLV-XVV for inspections (both FD2 and Late), new Battery charge attitude.	1/222 With OA 1/274
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O dump attitude, -ZLV-XVV for inspections (both FD2 and Late), new Battery charge attitude. –ZLV-XVV with _20 degree Pitch bias during HST berth.	1/224 With OA 1/277
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O Dump attitude (7 hrs), replace –ZLV-XVV with +ZLV-XVV pre HST berth and post release.	1/198 With OA 1/260
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O dump attitude, -ZLV-XVV for inspections (both FD2 and Late), new Battery charge attitude., replace –ZLV-XVV with +ZLV-XVV pre HST berth and post release.	1/242 With OA 1/304
•Nominal Timeline (FD2 and Late Inspection) with following mods: new H2O dump attitude, -ZLV-XVV for inspections (both FD2 and Late), new Battery charge attitude., replace –ZLV-XVV with +ZLV-XVV post HST release.	1/234 With OA 1/296

(A) Possible Options that require evaluation for operational feasibility (B) Per KX spreadsheet

Shuttle Crew Rescue Flight Concept

- **MOD Team reviewed the "Shuttle Crew Rescue Flight Concept" developed 2003.**
  - **MOD recommended change is to have the Rescue Vehicle grapple the HST vehicle.**
    - » **Easier/less-complex choreography between vehicles to obtain safe and successful grapple.**
      - **HST vehicle "Satellite' - Rescue vehicle "Controlling Vehicle"**
    - » **Requires "FGRF" install on HST ODS.**

LON Support

HST LON (Case #2) – Repair Attempt FD9/10 CSCS

FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9		Mission Duration
•Ascent •PI •Group B	•TPS Surveys	•RNDZ •HST Berth •Modified Group C	•Focused Inspection	•HST EVA#1	•HST Deploy	•EVA/TPS Repair	•Repair Inspection w/OBSS	•Group C+		19/13:00

FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	Mission Duration
•Ascent •PI •Group B	•TPS Surveys	•RNDZ •HST Berth •Modified Group C	•Focused Inspection	•HST EVA#1	•HST Deploy	•EVA/TPS Repair	•Repair Inspection w/OBSS	•Awaiting repair review results	•Group C+	19/05:00

NOTES

- Mission duration also includes Rendezvous w/Rescue vehicle and 1 Day of EVA Crew Transfer operations.
- Modified Group C minimal power level retains Orbiter systems to support nominal operations including Entry.
- Group C+ minimal power levels (7.8 KW) protects required systems for crew support and disposal burn (not Entry).
- Assumes "On-Time" Launch.

Additional Powerdown Requirements for Case #2 to support 25 Day MET

- Additional powerdowns cannot be initiated until FD9/FD10 (CSCS declaration/Group C+) since the vehicle is already at minimum power levels required to keep systems available for Entry.
  - The Orbiter would have to be powered down to ~ 4.8 KW from FD9 (~ 4.6 KW from FD10) to achieve to 25 days
    - Loss of Att Hold Capability, Possible Freezing of Freon Loop, Fuel Cell/Freon Loop Heat HX, Water Lines at Freon Loop HX.

HST LON (Case #3) – FD4 CSCS

FD1	FD2	FD3	FD4	Mission Duration
•Ascent •PI •Group B	•TPS Surveys	•RNDZ •HST Berth •Modified Group C	•HST Deploy •Group C+	22/15:00

NOTES

- Mission duration also includes Rendezvous w/Rescue vehicle and 1 Day of EVA Crew Transfer operations.
- Modified Group C minimal power level retains Orbiter systems to support nominal operations including Entry.
- Group C+ minimal power levels (7.8 KW) protects required systems for crew support and disposal burn (not Entry).
- Assumes "On-Time" Launch.

Additional Powerdown Requirements for Case #3 to support 25 Day MET

- Additional powerdowns cannot be initiated until FD4 (CSCS declaration/Group C+) to ensure all critical activities complete.
  - The Orbiter would have to be powered down to ~ 6.9 KW from FD4
    - Possible Freezing of Freon Loop, Fuel Cell/Freon Loop Heat HX, Water Lines at Freon Loop HX.

HST LON (Case #4) – FD2 CSCS

FD1	FD2	Mission Duration
•Ascent •PI •Group B	•TPS Surveys •Group C+	24/04:00

NOTES

- Mission duration also includes Rendezvous w/Rescue vehicle and 1 Day of EVA Crew Transfer operations.
- Modified Group C minimal power level retains Orbiter systems to support nominal operations including Entry.
- Group C+ minimal power levels (7.8 KW) protects required systems for crew support and disposal burn (not Entry).
- Assumes "On-Time" Launch.

Additional Powerdown Requirements for Case #4 to support 25 Day MET

- Additional powerdowns cannot be initiated until FD2/Post Surveys (CSCS declaration/Group C+) to ensure all critical activities complete.
  - The Orbiter would have to be powered down to ~ 7.5 KW from FD2 to achieve to 25 days

LON Support Extension

- **Powerdowns below 7 KW are at risk to freeze the Freon Loops, Fuel Cell to Freon Loop HX, and Water Loop to Freon Loop HX resulting in an Orbiter that has lost Heat rejection capability thus functional capability.**
  - **Thermal analysis is required for power levels below 7 KW to determine actual capability.**
- **With that being said, the chart below provides additional LON capability (focusing on Case #2) based on CRYO capability only (Thermal capability has not been analyzed).**

Additional Powerdown Requirements for Case #2 to support 30 Day MET

•The Orbiter would have to be powered down to ~ 3.4 KW from FD9 (~ 3.2 KW from FD10) to get to 30 days

Additional Powerdown Requirements for Case #2 to support 40 Day MET

•The Orbiter would have to be powered down to ~ 2.0 KW from FD9 (~ 1.9 KW from FD10) to get to 40 days

Additional Powerdown Requirements for Case #2 to support 45 Day MET

•The Orbiter would have to be powered down to ~ 1.6 KW from FD9 (~ 1.5 KW from FD10) to get to 45 days

ECLSS Support

- N2: ~ 35 Days
- LiOH
  - 88 cans/25 Day mission
    - » Nominal pre & post-sleep Change out.
  - 82 cans/25 Day mission
    - » Change out max limit of 7.6 mmHg
      - Every 16 hours (starting on FD10)
- Supply H2O Dumps (based on 7 KW Power Level)
  - 4 Dumps required for 25 days
- Waste H2O Dumps (based on nominal waste generation rate 7 crew)
  - 9 Dumps required for 25 days
- WCS (based on nominal waste generation rate 7 crew)
  - Can support ~ 17 days of use

* Again based on nominal usage/consumption rates. Usage (and resulting capabilities) will most likely be reduced in a CSCS/LON situation.

Back Up Charts

HST SM4 Overview Timeline with Late Inspection (Draft Timeline)
11 Day Mission (5 EVAs)