
YERO FSW Validation/checking for STS-116

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Summary

Nominal

- **YERO Procedure**
IPL of GPC's restores PASS FSW to a known configuration. Uplinks prepare the FSW for YERO, restore parameters lost due to the IPL, and update parameters post-YERO.
- **YERO Tests**
There's no new flight software code for YERO. Tests validate FSW capability to perform YERO procedure. Previous generic FSW testing is applicable for all events following completion of the YERO procedure.
- **FSW Audit**
All timing related parameters have been identified and there are no FSW constraints which would prevent execution of the YERO procedure or subsequent operations

Off-Nominal

- **Software Failures**
There are **NO** credible failure scenarios where software fails to load properly during the IPL process and this condition is **NOT** detected
- **Hardware Failures**
Hardware failures which could prevent or delay completion of the YERO procedure have been identified. YERO affects criticality of hardware but not likelihood of failure.
- **Timeline Events that Delay Execution of YERO Procedure**
Onboard Time and Nav State will degrade until IPL restores GPC use of MTU time. Accurate Nav state restored upon state vector uplink. Dynamic flight is not certified until YERO procedure complete. Attitude hold is unaffected.

YERO FSW Validation/checking Activities ¹

- Review of YERO FSW Procedure and test plans by YERO Investigation Team and cognizant boards and panels (FOICB, FOR, JOP)
- PASS Level 7 YERO SDF Tests
 - Tests demonstrate effects of YERO procedure on a realistic DPS system (FEU GPC's executing OI-30 FSW) and modeled environment
 - Test specifications reviewed by YERO Team and approved by SASCB
 - Two Level 7 6-DOF SDF test cases (Orbit/Deorbit and Entry)
 - 3-GPC (2 GN&C/1 SM) Orbit/Deorbit simulation exercises the PASS YERO procedure (part 1 and 2) and continues to Entry Interface
 - Entry simulation continues test to landing at KSC
 - Test case Analysis was completed with no issues
 - YERO PASS Performance Test Report distributed 11/07

YERO FSW Validation/checking Activities ²

- **BFS Level 7 YERO SDF Tests**
- **Test specifications reviewed by FSW community and approved by SASCB**
 - **Six (3 Deorbit and 3 Entry) Level 7 6-DOF SDF test cases**
 - **BFS listen, BFS engaged (1 PASS GN&C/1 BFS GPC), and BFS engaged following PASS failure**
 - **Tests perform YERO BFS (part 3) procedure, perform deorbit, and continue to entry and landing**
 - **Analysis completed 10/27/06 with no issues**
 - **YERO BFS Performance Test Report distributed 11/03**

YERO FSW Validation/checking Activities ³

- FSW YERO audit
 - PASS audit to identify time parameter constraints to performing YERO procedure
 - Completed 10/31/06 with no issues
 - BFS audit to assess new operational requirements and time parameter constraints
 - Completed 10/25/06 with no issues

YERO FSW Validation/checking Activities 4

- **Fail Op/Fail Safe Assessment**
 - Since previous analyses had not considered executing an On-Orbit IPL in a no-fail scenario, system analyses were performed to determine if the system components required to execute the YERO procedure:
 - can tolerate one failure during YERO procedures and remain operational
 - can tolerate two failures during YERO procedures and remain in a safe configuration
 - Participation/inputs by Engineering, Orbiter, Safety, FSW and MOD
 - Results
 - Certain vehicle hardware was identified as being critical to the execution of the YERO procedures (MMU's, FF1- FF4, NSP's, PCMMU's, IPL Source Switch, Uplink Block Switch, S-Band)
 - Due to the execution of the YERO procedure, these devices may require an increase in criticality or required redundancy
 - Results have been forwarded to MOD and Safety for potential changes to Flight Rules, FMEA's, CIL's, LCC's, and MEL's

YERO FSW Validation/checking Activities ⁵

- **YERO SAIL/MCC Test**
 - Objective of the test is to perform end to end validation (crew, Orbiter, MCC) of the YERO procedure in the most realistic environment available
 - Test was co-sponsored by MOD and Boeing IAV
 - Test plan and procedures reviewed and approved
 - Test support by MCC, SAIL, GSFC and MER
 - Test completed 10/25/06 with no significant issues

YERO Procedure Summary

- **Part 1 of the procedure prepares the FSW for YERO**
 - **MTU MET is adjusted to roll over with GMT at the year end boundary**
 - **IMU's are aligned to identity matrix REFSMMAT's**
- **After the YERO event, the GPC FSW increments GMT to day 366, while the MTU GMT rolls over to day 1**
 - **The FSW declares an MTU fault and begins to use the internal GPC clock**
- **Part 2 of the procedure configures the FSW for operations in the new year**
 - **IPL's make the GPC's use MTU time and restore the PASS FSW to a known configuration**
 - **Uplinks provide updates for post-YERO conditions**
 - **The IMU's are aligned to the correct REFSMMAT's**
- **The Part 3 YERO procedure updates the BFS for new year operations**

Initial Program Load for YERO

- The YERO procedure incorporates a step that places PASS GPC's in HALT mode, and subsequent steps that re-IPL the PASS GPC's
- Unlike an on-orbit IPL following a GPC malfunction, IPL's for YERO are performed on GPC's that were deliberately powered off while in good operating condition
- The GPC IPL process typically completes within 2 minutes
 - Progress indications are provided by hardware indicators
 - When the IPL is successfully completed, PASS displays appear in the MDU's
- The IPL process is highly reliable
 - Operational experience at KSC indicates only 19 IPL failures for all causes, including reversible errors, out of a total 12,500 attempts

YERO FSW Validation/checking Results Summary

- Level 7 PASS and BFS SDF performance verification tests and SAIL/MCC/Network tests exercising the YERO procedure with the OI-30 STS-116 flight software were conducted without significant problems
- FO/FS analysis identified orbiter hardware which is critical to successfully performing the YERO procedures and restoring FSW functionality
 - Identified items have been forwarded to MOD and Safety for possible updates to STS-116 related Program documentation (e.g., flight rules, FMEA's/CIL's)
- The PASS and BFS flight software YERO audits were completed—no problems identified with software support of the YERO procedure
- All FSW systems are ready to support the defined STS-116 YERO activities
 - PASS, BFS, MEDS, MAGRS-3S, and PGSC can successfully perform the YERO procedures and safely react to the YERO event

BACKGROUND MATERIAL

Initial Program Load in YERO Procedure

- The YERO procedure incorporates a step that places PASS GPC's in HALT mode, and subsequent steps that re-IPL the PASS GPC's
- Unlike an on-orbit IPL following a GPC malfunction, IPL's for YERO are performed on GPC's that were deliberately powered off while in good operating condition
 - In the YERO scenario, GPC's are re-IPL'ed to ensure a clean slate memory for operations in the new year
 - The YERO procedure IPL does not incorporate a GPC memory dump, since no GPC malfunction is involved
 - The GPC IPL process typically completes within 2 minutes
 - Progress indications are provided by hardware indicators
 - When the IPL is successfully completed, PASS displays appear in the MDU's

Initial Program Load Process ¹

- An Initial Program Load can be initiated via the Multifunction Display Units (MDU's) and/or via crew-positioned hardware switches
- The GPC's IPL for YERO is initiated via hardware switches (default IPL)
- An IPL is initiated when the GPC is powered up and in HALT state; an MMU must also be powered up and selected via the GPC IPL Source switch
- Loading of the Bootstrap Loader from the MMU is initiated by a panel-mounted IPL push button switch
 - The Bootstrap Loader is stored in 2 locations in each MMU
- When the Bootstrap Loader loads successfully, it loads the GPC IPL program from the MMU
 - The GPC IPL program is stored in 3 locations in each MMU

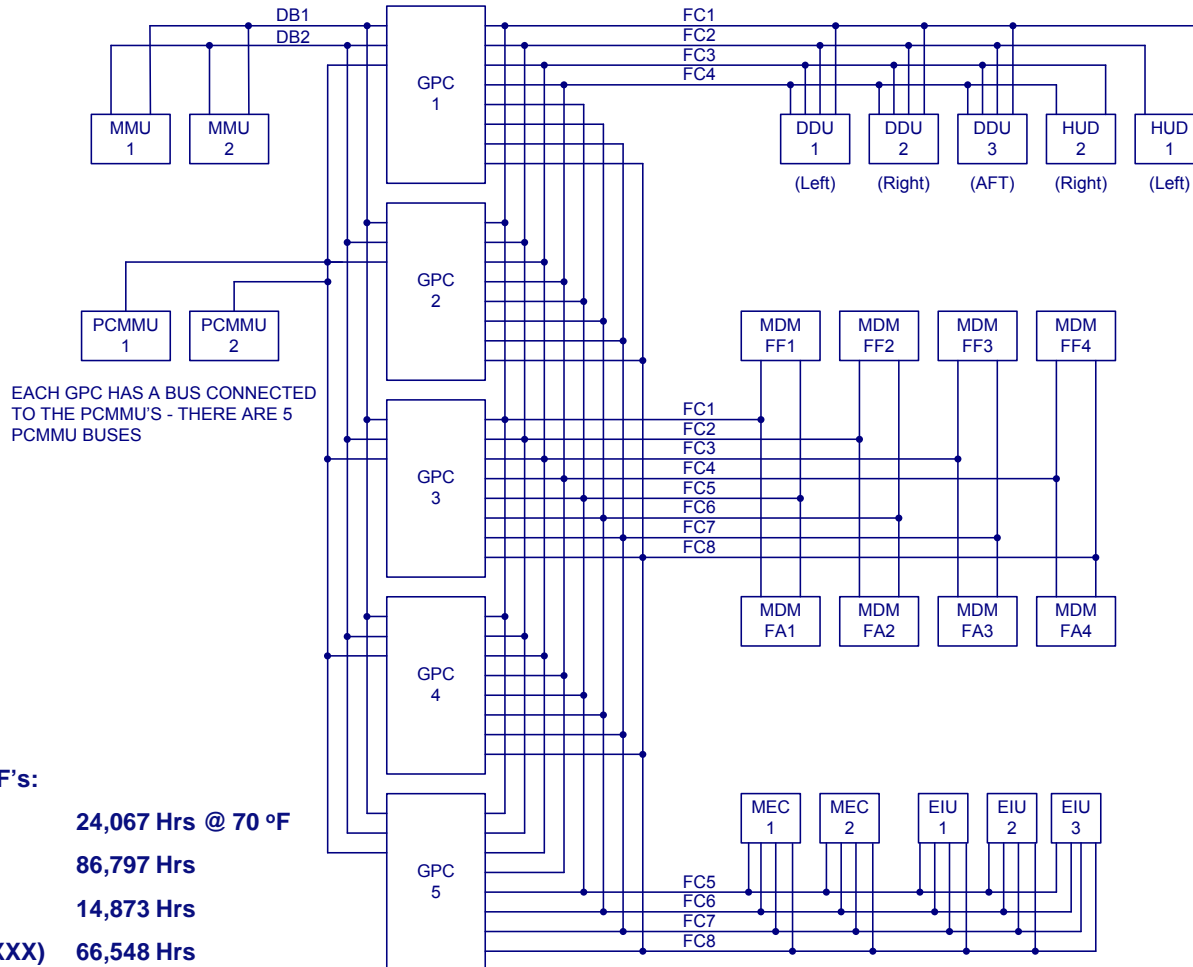
Initial Program Load Process 2

- When the GPCIPL program loads successfully, the Software System Loader In the GPCIPL program loads the PASS system software
 - The PASS software is loaded in 3 locations in each MMU
- In the IPL process, the software being loaded in the GPC undergoes a checksum before each load step is declared complete
- The System Software Loader checksums the PASS system software load
 - Upon a successful checksum, a SSW initialization routine executes
 - The GPC Mode Indicator is driven from Barberpole to RUN
- The crew then sets the GPC Mode switch to RUN and the GPC IPL Source switch to OFF
 - Control is turned over to PASS SSW
 - The GPC proceeds to execute the PASS SSW programs

Reliability of the Initial Program Load Process

- IPL statistics from KSC records
 - Total AP101S GPC IPL's (1991-present) at KSC across all vehicles, all slots = 12,500
 - Total KSC IPL failures on AP101S GPC's = 19
 - 8 = Explained Condition (configuration, human error, etc)
 - 8 = Tape MMU's, including UA's with Most Probable Cause = MMU
 - 2 = undetermined (UA, MPC unknown)
 - 1 = SSMM
 - Computed probability of a successful first attempt GPC IPL
 - $(12,500 - 19)/12,500 = 0.99848$
 - Computed probability of a successful IPL, excluding configuration, human error, etc.
 - $\{(12,500 - 8) - 11\} / (12,500 - 8) = 0.99912$

GPC Connectivity to DPS Components



ORU MTBF's:

MMU	24,067 Hrs @ 70 °F
GPC	86,797 Hrs
PCMMU	14,873 Hrs
MDM's (6XXX)	66,548 Hrs

C. B. Valrand 10 Nov 2006

Initial Program Load Summary

MMU Power Switch	GPC Power Switch	GPC IPL Source Switch	IPL Push Button	GPC Output Indicator	GPC Mode Switch	GPC Mode Indicator	GPC State
OFF	OFF	OFF	OFF	Barberpole	HALT	Barberpole	PASS GPC's in HALT
ON	ON	MMU 1	PRESS	Barberpole	HALT	IPL	Initiate IPL
ON	ON	MMU 1	OFF	Barberpole	HALT	Barberpole	Bootstrap Loaded
ON	ON	MMU 1	OFF	Barberpole	STBY	Barberpole	GPCIPL Program Loaded
ON	ON	MMU 1	OFF	Barberpole	STBY	RUN	PASS SSW Loaded
ON	ON	OFF	OFF	Gray	RUN	RUN	PASS Programs Begin to Execute

PASS Level 7 YERO SDF Test Results 1

Time Parameters at Start of Simulation

The Orbit/Deorbit test case was initialized 30 minutes before the year end

Event	FSW GMT	FSW MET	MTU GMT	MTU MET
Initialization	365:23:30:00	10:17:45:29	365:23:30:00	10:17:45:29
Before MET adjust	365:23:36:25	10:17:51:54	365:23:36:25	10:17:51:54

An MET delta update was performed equal to one day less than the computed difference between GMT time and MET time

Time Parameters Before YERO Event

Event	FSW GMT	FSW MET	MTU GMT	MTU MET
After MET adjust	365:23:59:10	364:23:59:10	365:23:59:10	364:23:59:10

An identity matrix REFSMMAT was uplinked and the IMU's were aligned to the identity matrix REFSMMAT

After the YERO event, the GPC continued to increment time, while the MTU times rolled over (GMT to day 1, MET to day zero)

Time Parameters After YERO Event

Event	FSW GMT	FSW MET	MTU GMT	MTU MET
After YERO	366/00:00:01	365/00:00:01	001/00:00:01	000/00:00:01

TIME MTU Faults were annunciated

Reference: YEROC Case 1 Performance Test Report, USA010951, 11/07/2006

PASS Level 7 YERO SDF Test Results 2

YERODNOM
 FET = 12/11.8079 MAJOR FN = GN&C VASPO442 DEU2
 10/19/06 372
 000/00:00:00

```

2011/002/      TIME          2 010/17:57:40
                                000/00:00:00

MISSION TIME          TONE
GMT 1                 3         MSN T
MET 2*                6

CRT TIMER
9 SET[]              20]         CRT T
START 12  STOP 13
14 START AT          MSN T 23 DURATION 01
17 COUNT TO          MSN T

MTU
24 GMT D[] / : :
28 MET D[+354/05:44:31.300
  UPDATE 32          MET RESET 33

GPC TIME              GPC
GMT                  TRY 1A1
MTU ACCUM 1 365/23:42:11.069 34 2A1
                2 365/23:42:11.069 35 3A1
                3 365/23:42:11.069 36 4A1
  GPC 365/23:42:11.069 37 5A1

TIME SYNC 38
S66 CABIN  PRES *    3         17:55:53( 6)

ITEM 28+354+05+44+31.3 EXRC
    
```

TIME Display Showing Delta MET Update

YERODNOM
 FET = 32/51.0290 MAJOR FN = GN&C VASPO442 DEU2
 10/19/06 1011
 000/00:00:00

```

2011/ /          UNIV PTG      1 001/00:02:51
  CUR MNVR COMPL 00:00:00      000/00:00:00
1 START TIME 000/00:00:00

                                CUR FUT      CUR FUT
MNVR OPTION  START MNVR 18      RBST 25
5 R 0.00      TRK 19           CNCL 26
6 P 0.00      ROT 20           DURATION 27
7 Y 0.00      CNCL 21          0:00:00.00

TRK/ROT OPTIONS  ATT MON
8 TGT ID 2       22 MON AXIS 1 +X
                                ERR TOT 23 *
                                ERR DAP 24

9 RA 000.000
10 DEC []00.000
11 LAT []00.000      ROLL  PITCH  YAW
12 LON[]000.000     CUR  0.00  10.60  0.00
13 ALT[]00000.0     REQD  0.00  10.60  0.00
                                ERR  0.00  0.00  0.00
14 BODY VRCT 1     RATE  0.000  0.000  0.000

15 P 000.00
16 Y 000.00
17 OM 000.00
    
```

OPS G2 PRO After YERO Event

Reference: YEROC Case 1 Performance Test Report, USA010951, 11/07/2006

PASS Level 7 YERO SDF Test Results 3

Time Parameters Before GPC IPL

After the YERO event, GPC's used internal clock time

Event	FSW GMT	FSW MET	MTU GMT	MTU MET
Before IPL	366/00:01:50	365/00:01:50	001/00:01:50	000/00:01:50

GPC's were brought to Standby and then Halt to prepare for the new-year MTU time

Time Parameters After GPC 1 IPL

Then GPC 1 was IPL'ed and it accepted MTU time for the new year

Event	FSW GMT	FSW MET	MTU GMT	MTU MET
After IPL	001/00:02:11	000/00:02:11	001/00:02:11	000/00:02:11

RNP time parameters, state vector, GPS SOP time adjustment, correct REFSMMAT, Orbiter weight, etc., were uplinked to restore information lost during the IPL and update values for the current time

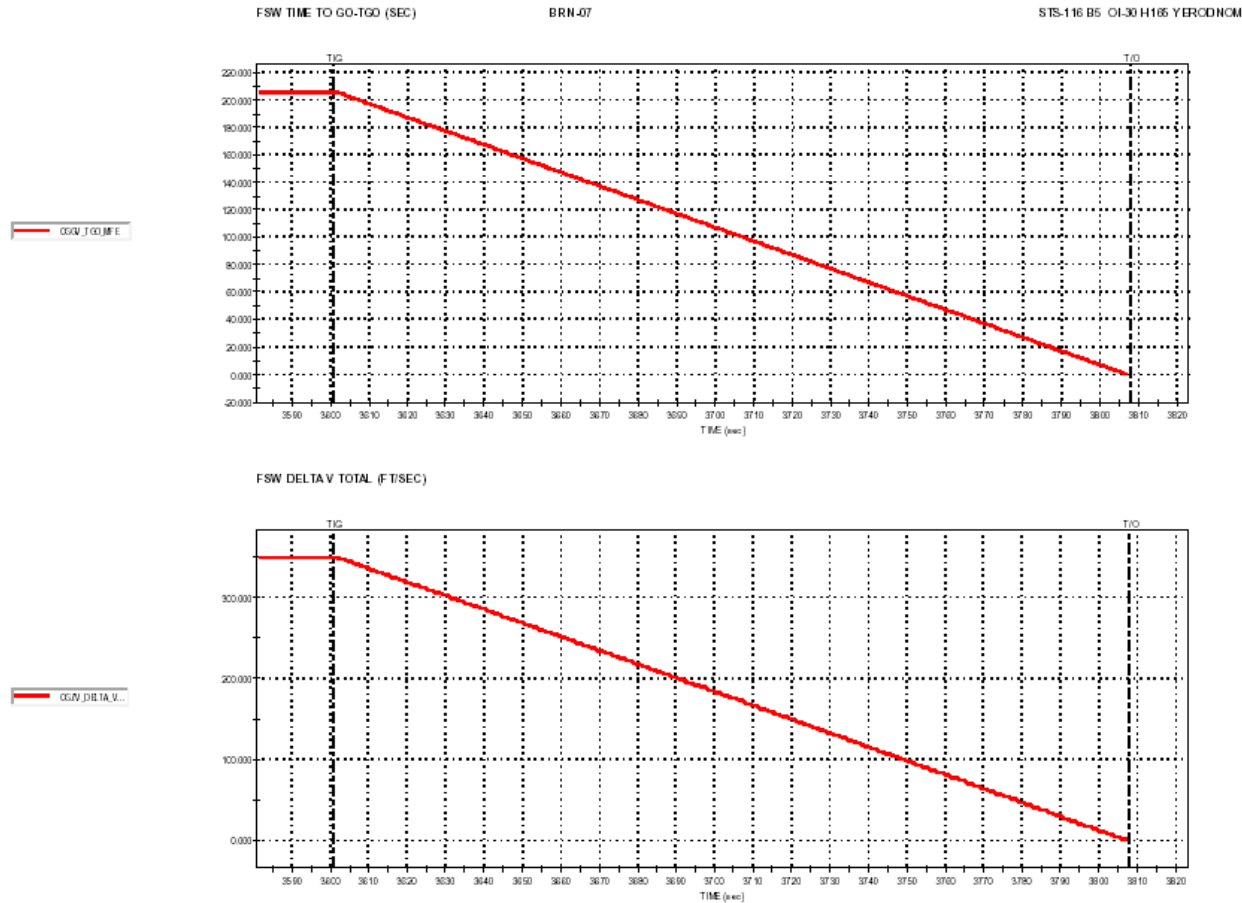
Subsequently, GPC's 2 and 3 were IPL'ed

GPC 3 was configured for SM, and GPC's 1 and 2 were set to a redundant GNC GPC configuration

The IMU's were aligned to the correct REFSMMAT

Reference: YEROC Case 1 Performance Test Report, USA010951, 11/07/2006

PASS Level 7 YERO SDF Test Results 4



Time to go and Total Delta V During Deorbit OMS Burn

Reference: YEROC Case 1 Performance Test Report, USA010951, 11/07/2006

PASS Level 7 YERO SDF Test Results 5

YERODNOM

10/19/06 1216
FET = 1/03/27.8307 MAJOR FN = GN&C VASP0441 DEU1

3021/ /	DEORB MNVR EXEC	1 001/00:33:28
OMS BOTH 1*		000/00:03:28
L 2	BURN ATT	
R 3	24 R 062	DVTOT 0.0
RCS SEL 4	25 P 212	TGO 0:00
5 TV ROLL 180	26 Y 054	
TRIM LOAD	MNVR 27 AUTO	VGO X - 0.01
6 P [-0.1	TTG	Y + 0.00
7 LY[-5.7	REI 4425	Z - 0.04
8 RY[+5.7	TFF 30:57	
9 WT 226917	GMBL	HA HP
10 TIG	L R	TGT 185 + 22
0/00:30:00.2	P +0.7 +0.9	CUR 185 + 22
TGT PEG 4	Y -6.0 +5.4	
14 C1 14925		
15 C2 [-0.5957	PRI 28* 29*	35 ABORT TGT
16 HT 65.831	SEC 30 31	
17 OT 141.604	OFF 32 33	FWD RCS
18 PRPLT[+ 11		ARM 36
TGT PEG 7	GMBL CK 34	DUMP 37
19 DVX[+ 0.0		OFF 38*
20 DVY [+ 0.0		SURF DRIVE
21 DVZ [+ 0.0		ON 39
LOAD 22/TIMER 23		OFF 40*
GPC 3 * 12		00:24:35
EXEC		

MNVR Display Showing OMS Burn Complete

YERODNOM

10/19/06 1441
FET = 1/09/49.4235 MAJOR FN = GN&C VASP0441 DEU1

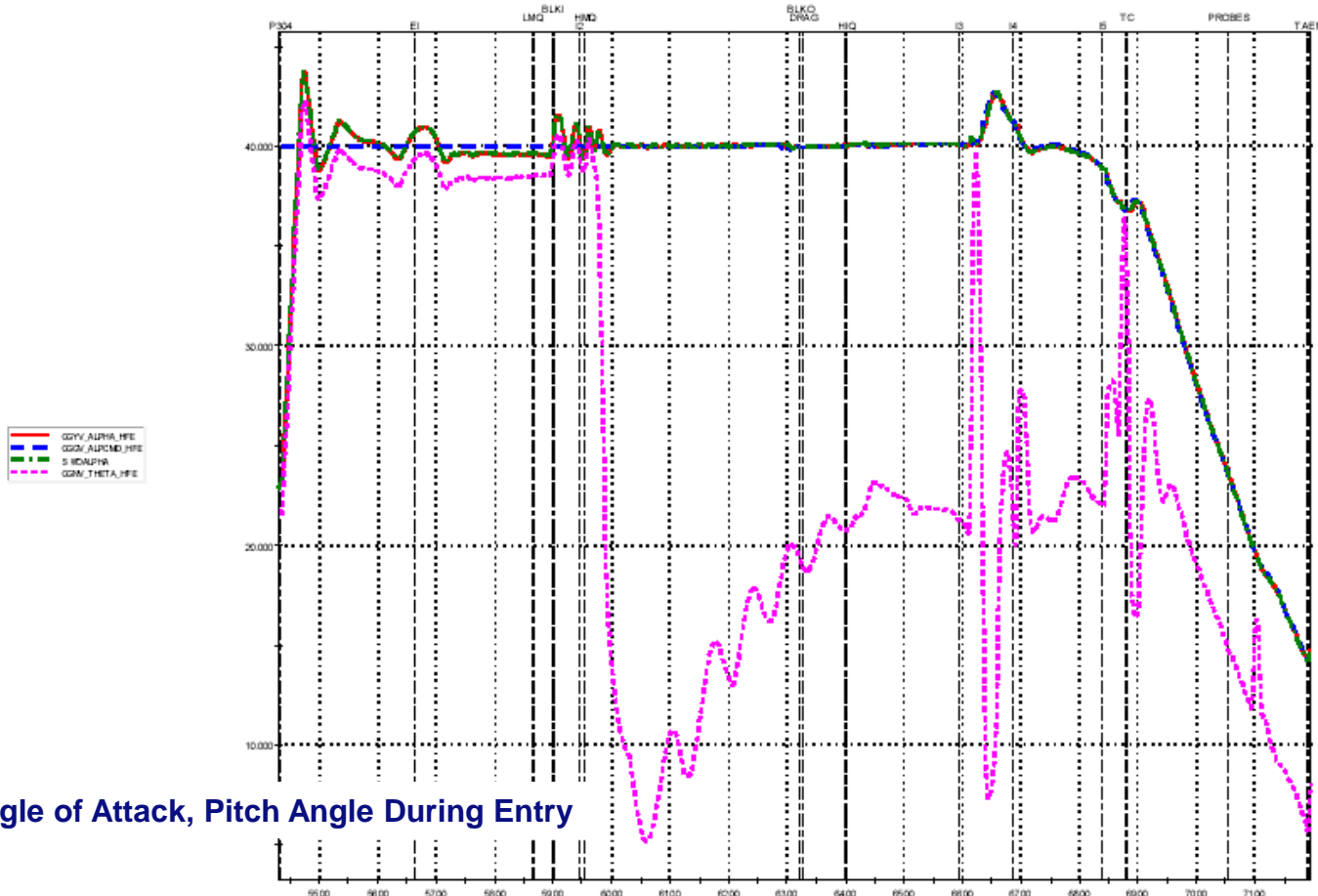
3031/ /	DEORB MNVR COAST	1 001/00:39:49
OMS BOTH 1*		000/00:24:34
L 2	BURN ATT	
R 3	24 R 328	DVTOT
RCS SEL 4	25 P 350	TGO
5 TV ROLL 180	26 Y 027	
TRIM LOAD	MNVR 27* AUTO	VGO X
6 P [+0.7	TTG 00:01	Y
7 LY[-5.8	REI 4425	Z
8 RY[+5.6	TFF 29:21	
9 WT 226861	GMBL	HA HP
10 TIG	L R	TGT
0/00:30:00.2	P +5.8 +5.8	CUR 185 + 22
TGT PEG 4	Y +6.3 -6.3	
14 C1 14925		
15 C2 [-0.5957	PRI 28* 29*	35 ABORT TGT
16 HT 65.831	SEC 30 31	
17 OT 141.604	OFF 32 33	FWD RCS
18 PRPLT[+ 66		ARM 36
TGT PEG 7	GMBL CK 34	DUMP 37
19 DVX[] .		OFF 38*
20 DVY [] .		SURF DRIVE
21 DVZ [] .		ON 39
LOAD 22/TIMER 23		OFF 40*
GPC 3 * 12		00:24:35(3)
ITEM 27 EXEC		

MNVR Display Showing Pre EI Maneuver Complete

Reference: YEROC Case 1 Performance Test Report, USA010951, 11/07/2006

PASS Level 7 YERO SDF Test Results 6

ALPHA(DEG) FSW, CMD, ENV & THETA G-5 01-30 YEROC02



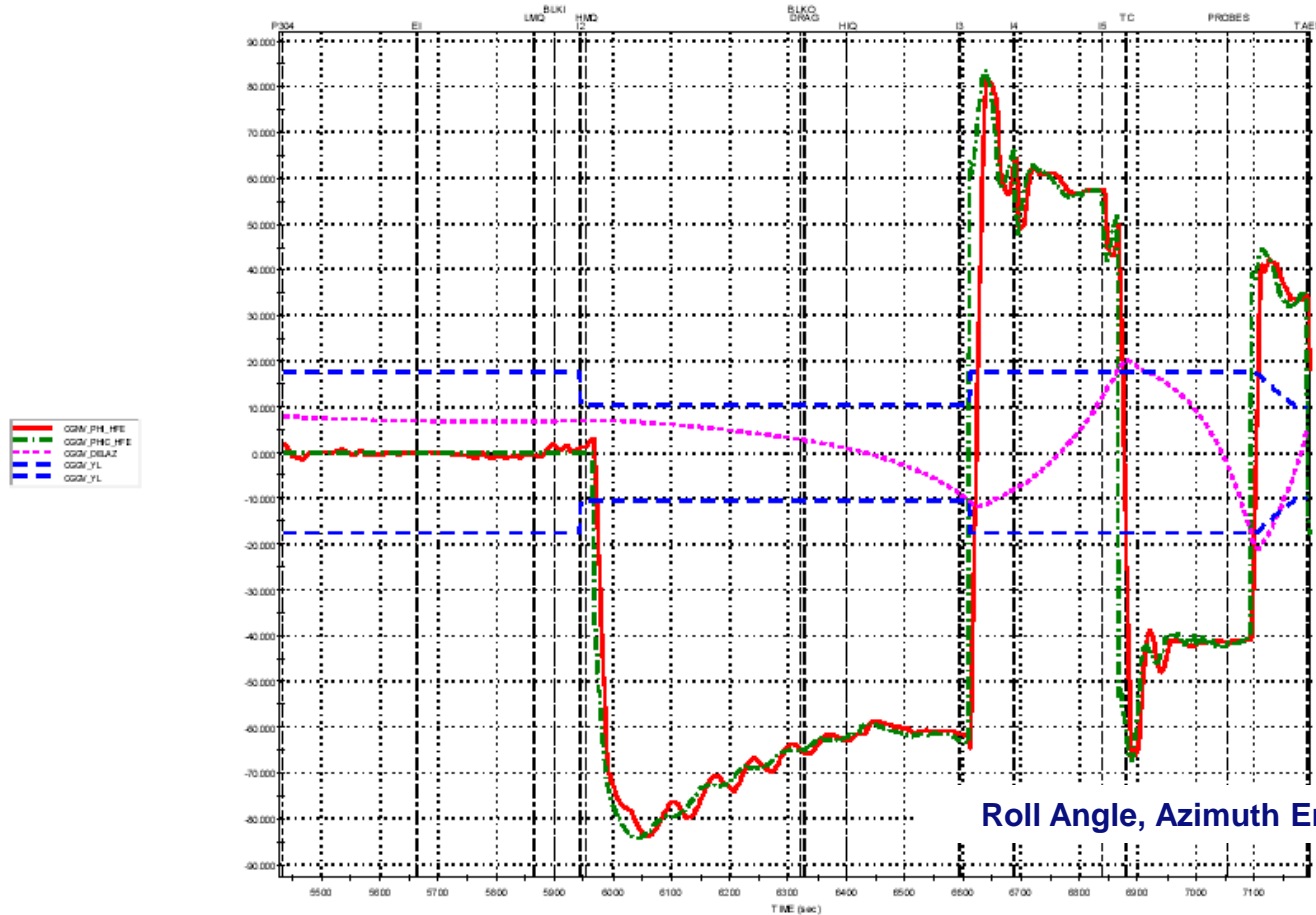
Angle of Attack, Pitch Angle During Entry

Reference: YEROC Case 2 Performance Test Report, USA010952, 11/07/2006

PASS Level 7 YERO SDF Test Results 7

ROLL (DEG) FSW, CMD & DELAZ & HEADING ERROR LIMITS G-3

01-30 YEROC02



Roll Angle, Azimuth Error During Entry

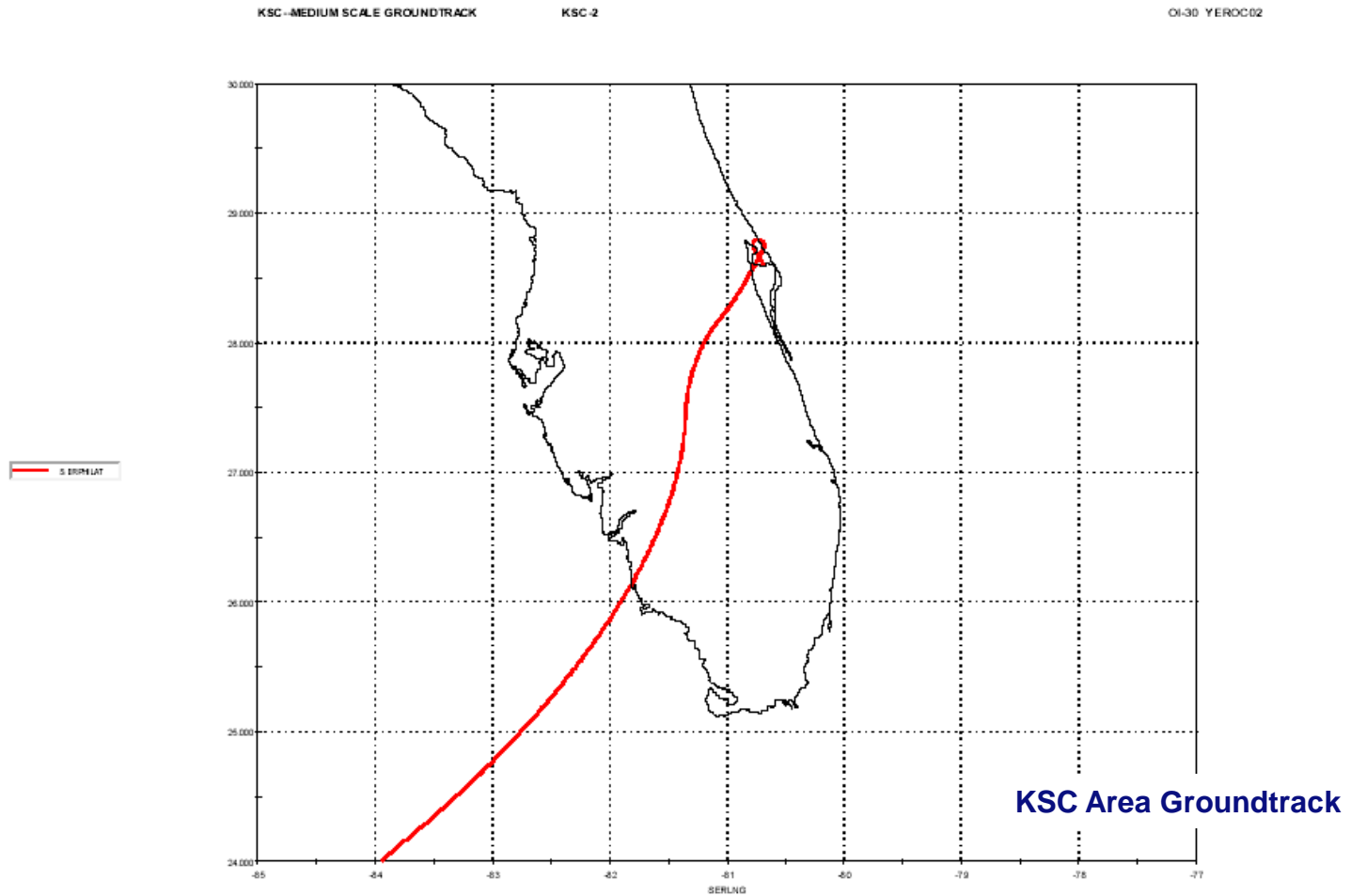
Reference: YEROC Case 2 Performance Test Report, USA010952, 11/07/2006



FSW YERO VALIDATION/CHECKING



PASS Level 7 YERO SDF Test Results 8

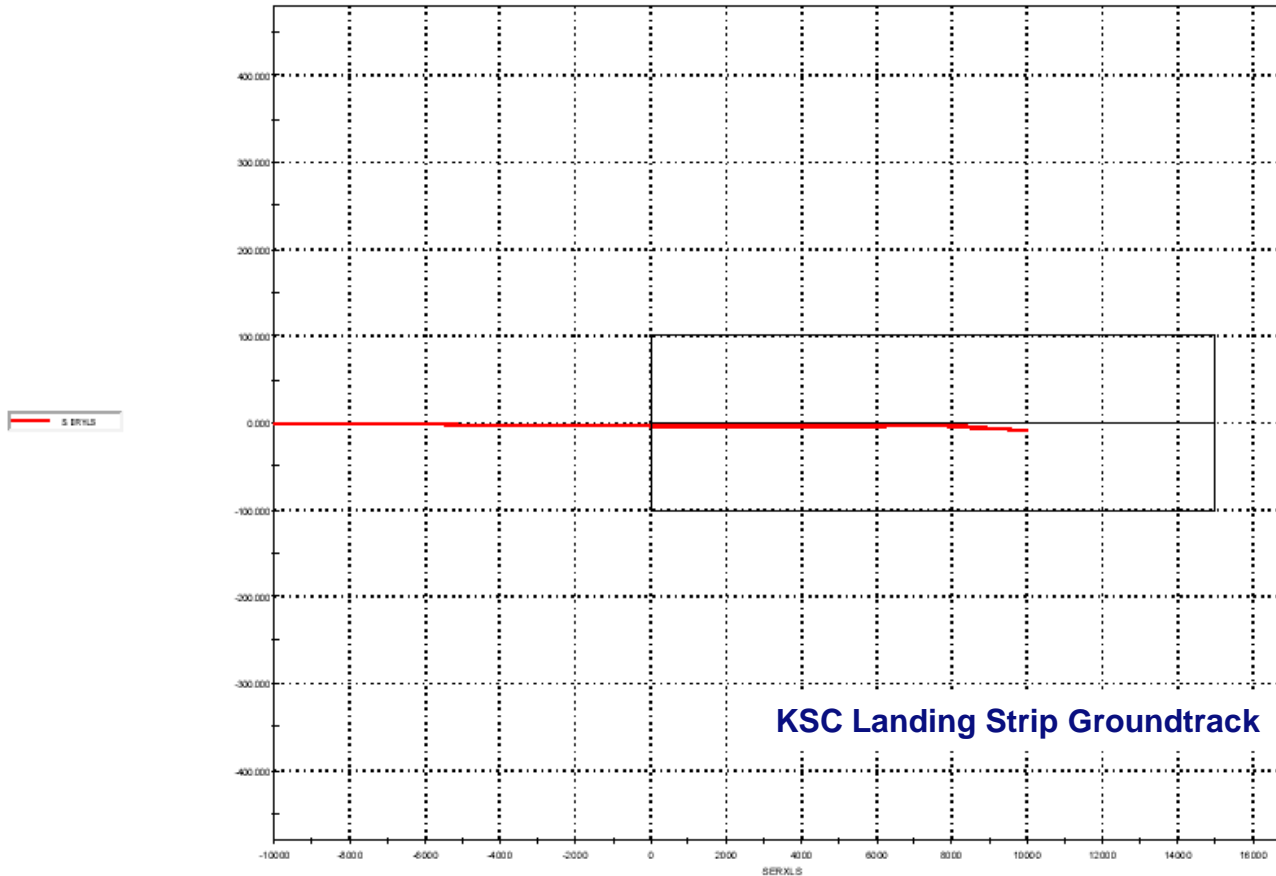


Reference: YEROC Case 2 Performance Test Report, USA010952, 11/07/2006

PASS Level 7 YERO SDF Test Results 9

ENV - LANDING STRIP GROUNDTRACK - LS COORDINATES HAC-3

01-30 YEROC02



Reference: YEROC Case 2 Performance Test Report, USA010952, 11/07/2006