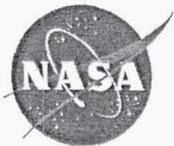


# Improved Situational Awareness Produced by the Space Shuttle Cockpit Avionics Upgrade

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United Space Alliance



# CAU Operational Objective

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**To increase situational awareness and reduce cockpit workload resulting in the execution of more accurate and timely decisions**

note: crew error reportedly responsible for the majority of civil and military aeronautical accidents



## Background

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The Shuttle has complex flight regimes:

- Launch rocket for approximately 9 minutes
- Orbital spacecraft for 10-14 days
- Hypersonic plane for an hour
- Subsonic glider about 5 minutes

Large operational flight envelope is further complicated by an extremely large set of monitoring tasks and procedures over 10 major subsystems

- Propulsion, Guidance & Navigation, Flight Control, Hydraulics
- Power, Thermal, Environmental
- Data Processing, Communications
- Payloads

NASA chooses the “Best of the Best” for its astronauts

- Experienced test pilots with thousands of hours in 40+ aircraft

**Minimum time required to train a shuttle pilot is 2-3 years!**



## Improved Situational Awareness

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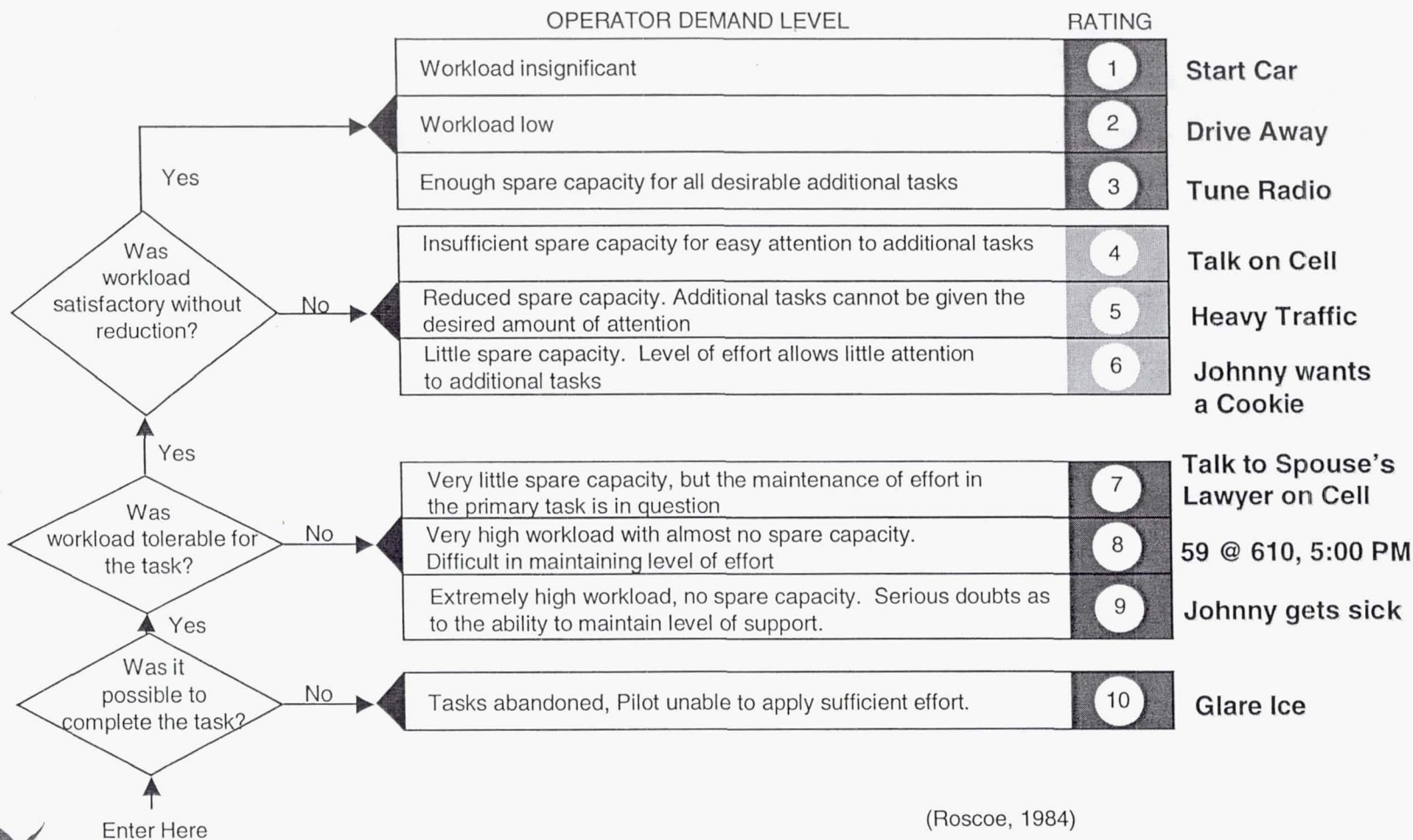
- Situational Awareness (SA) is an understanding of the state of the environment
  - It provides the PRIMARY basis for subsequent decision making and performance in the operation of complex, dynamic systems
- What detracts from situational awareness?
  - Too much data
  - Too little time
  - Lack of information
  - High workload
  - Malfunctions
  - Environmental distractions  
(noise, vibration, visibility, etc.)
- What are the consequences when these come together?

### Errors can be, and are, made

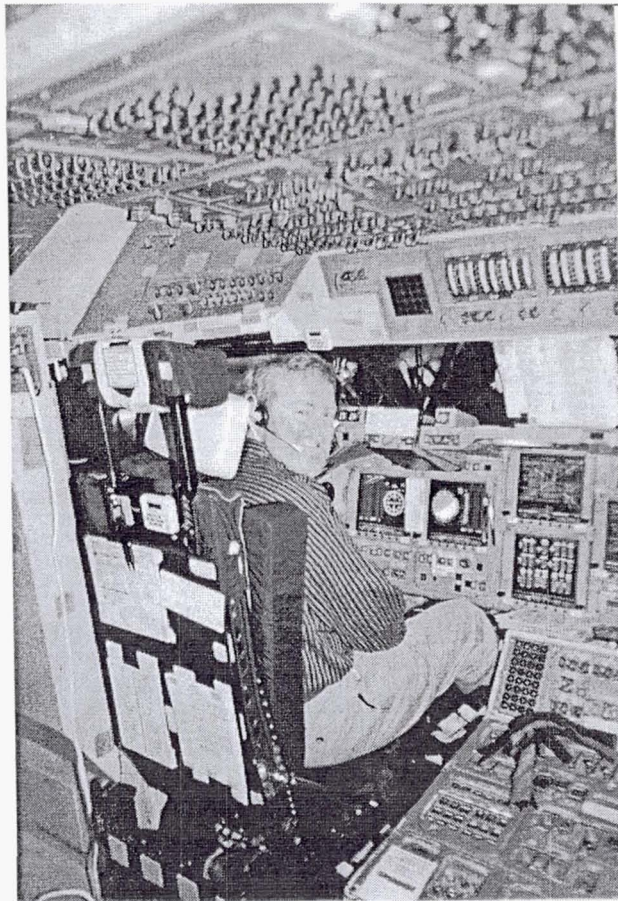
- Display navigation/command inputs
- Problem diagnosis and resolution



# Bedford Workload Scale



# Shuttle Cockpit is a Complex Work Environment



- 100+ time/safety critical dynamic flight procedures
  - Aborts to KSC, East Coast, Spain, Africa, Orbit
- ~1000 on orbit procedures
  - Systems, Payloads, Mission Objectives
- On orbit in-flight maintenance procedures designed in real-time
  - Problem diagnosis and repair
- Signature Recognition required for almost every procedure
  - Obscure problems are recognized by specific 'Christmas Tree' warning light patterns
- Rote memorization required in display navigation and problem diagnosis
  - Backed up by hundreds of pages of printed manuals



# Legacy Displays to support OMS Burn Task

3821/ /010 OMS BURN EXEC 1 004/10:00:42 000/00:00:41

OMS BOTH 1= L 2= R 3= S

RCS SEL 4

0 TV ROLL 100

TRIM LOAD

0 P +0.0

7 LY -0.7

0 RY +0.7

0 WT 244000

10 TIO

4/10:0:0:0:0:0

TOT PEG 4

14 C1 10010

16 C2 -0.0000

18 HT 00.000

17 0T 113.074

18 PRPLT 20000

TOT PEG 7

19 AVK =227.2

20 AVY -200.0

21 AVZ 207.1

LOAD 22/TIMER 23

L OMS PC

EXEC

BURN ATT

24 R 00

25 P 40

26 Y 00

MNVR 27\*

REI 4100

TFF 21:02

OMBL

L R

P +0.0 +0.0

Y -0.7 +0.7

PRI 20= 20=

SEC 30 31

OFF 32 33

OMBL CK 34

AVTOT 300.7

T00 3:30

V00 X +320.04

Y +10.00

Z +120.24

HA HP

TOT 101 +20

CUR 100 +130

30 ABORT TOT 0

FWD RCS

ARN 30

DUMP 37

OFF

SURF I

ON

OFF

1234 10:00

DPS MENU

PC4

3821/ /010 OMS BURN EXEC 1 004/10:02:40 000/00:00:00

OMS APT STY L R

OXID 30.1 10.0

FU 30.1 10.0

FU INJ Y 101 240

JETSOL

NO TK P 2100 2170

REG P 200 200

P VLV CL OP

END IN P

OXID 240 100

FU 240 210

VLV 1 0 100

2 0 100

3 0 100

4 0 100

JETSOL

OXID 2710 2710

TK P 240 240

QTY 00 00

1 P 240 240

2 P 240 240

3 P 240 240

4 P 240 240

5 0 240 240

DPS MENU

PC4

OMS

L R

2000 2000

He TK P

2100 2100

N2 TK P

MPS

PNEU 0200

L/2 C/1 R/2

0200 0200 0200

He TANK P

REG P

He REG A

0700 0700 0700

ENG MANF

LO2 LM2

L/2 C/1 R/2

100 100 100

0300 0300

P S I A

He

He

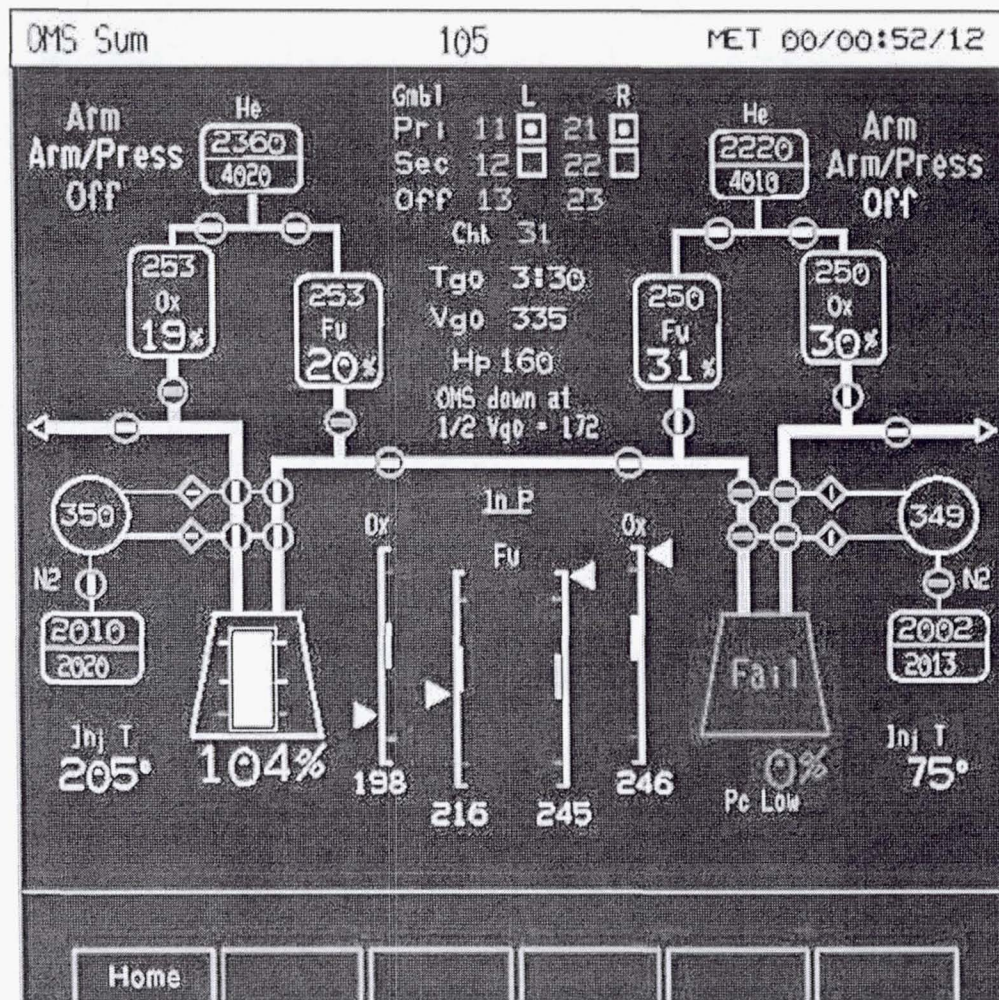
He

SUBSYSTEM MENU

PC4



# CAU Display to support OMS Burn Task





# Legacy Electrical Monitoring Displays

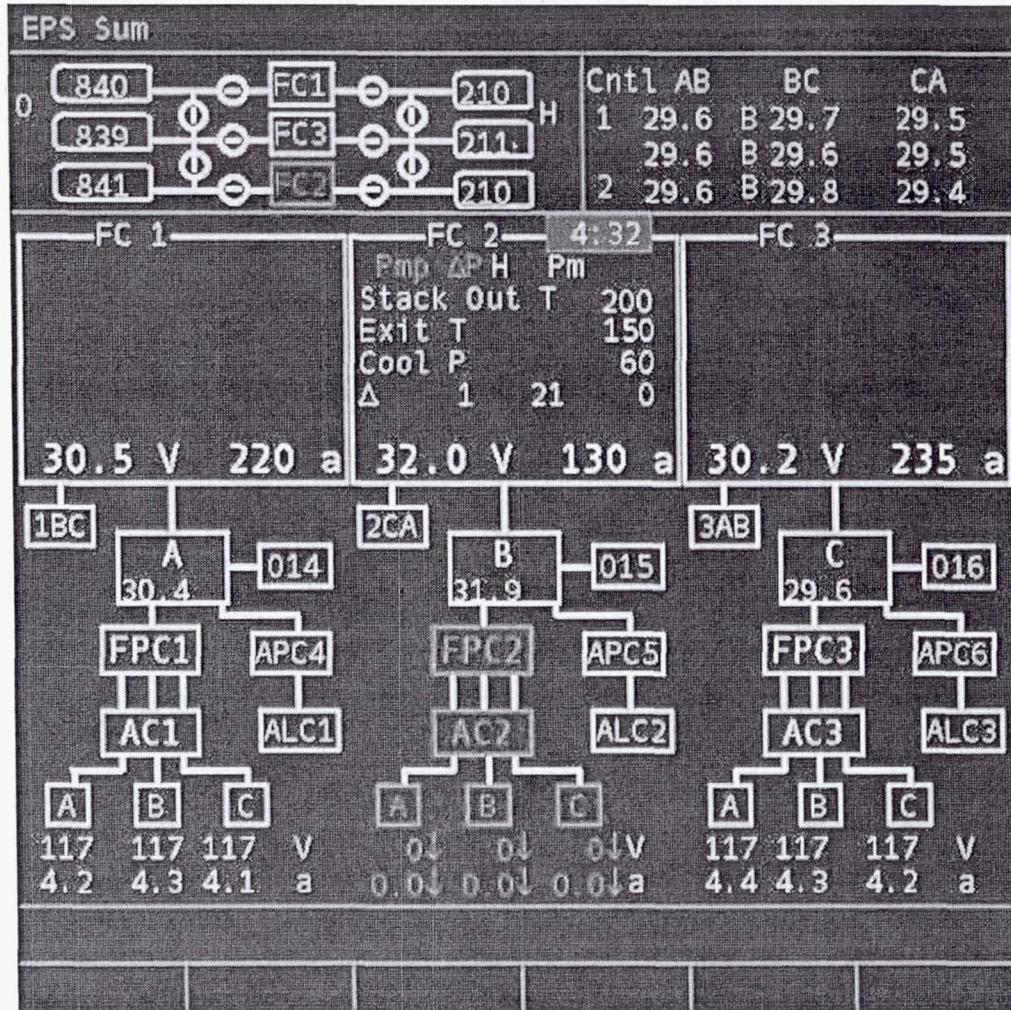


0881/ /078		0M SYS SUMM 1		0 088/08:00:00		
SMOKE	1/A 2/B	DC VOLTS	1/A	2/B	3/C	
CABIN	0.0	FC	30.2	0.0L	28.3	
L/R FD	0.0 0.0	MAIN	28.2	28.3	28.3	
AV BAY	1 0.0 0.0	CNTL	AD 28.6	28.6	28.6	
	2 0.0 0.0	BC 28.6	28.6	28.6		
	3 0.0 0.0	CA 28.6	28.6	28.6		
CABIN		EBB	28.6	28.6	28.6	
PRESS	14.0	AC				
OP/DT	+1.00	VOLT	0A 118	118	117	
BU/EG	+1.00 +1.00	0B	117	117	116	
PP02	3.00 3.00	0C	117	117	118	
FAN AP	0.00	AMPS	0A 0.4	4.3	3.0	
HX OUT T	0	0B	0.8	4.8	4.3	
O2 FLOW	0.0 0.0	0C	3.4	4.2	4.1	
N2 FLOW	0.0 0.0	FUEL CELL PH				
IMU FAN AP	0.00	AMPS	220	0L	4858	
AV FC1 FC2 FC3		REAC VLV	OP	CLS	OP	
SS1 22 0L 22		STACK T	+204	+2228	+200	
SS2 22 0L 23		EXIT T	+151	+1738	168	
SS3 23 0L 21		COOL P	00	100	00	
TOTAL AMPS	034	PUMP		APB		
KU	16					
SYS SUMM						
		2				
P2=	01	DPS MENU		MEMS	MEMS	FC4
				M00 ROT	M00 ACHAUT	

0881/ /078		0M SYS SUMM 2		0 084/10:04:10		
CRVO TK	1 2 3 4	02 PRESS	210 210 230 230	230	230	230
O2 PRESS		HTR T1	-104 -104 -137 -137	-137	-137	-137
HTR T2		T2	-104 -104 -137 -137	-137	-137	-137
APU	1 2 3	HYD	1 2 3			
TEMP EOT	0 0 0	PRESS	0 0 0			
B/U EOT	0 0 0	ACUM P	0 0 0			
OIL IN	0 0 0	RSVR T	0 0 0			
OUT	0 0 0	QTY	0 0 0			
00 BED	0 0 0					
INJ	0 0 0	W/S				
SPEED R	0 0 0	H2O QTY	0 0 0			
FUEL QTY	0 0 0	BYP VLV	BYP BYP BYP			
PMP LK P	0 0 0					
OIL OUT P	0 0 0					
FU TK VLV						
A T	0 0 0	THRM CNTL	1 2			
B T	0 0 0	H2O PUMP P	00 00			
AV BAY	1 2 3	FREON FLOW	2000 2000			
TEMP	00 0 0	EVAP OUT T	00 00			
FAN AP	0.00 0.00 0.00					
SYS SUMM						
		2				
P2=	01	DPS MENU		MEMS	MEMS	FC4
				M00 ROT	M00 ACHAUT	



# CAU Electrical System Summary Display



# Legacy Ascent Horizontal Situation Display

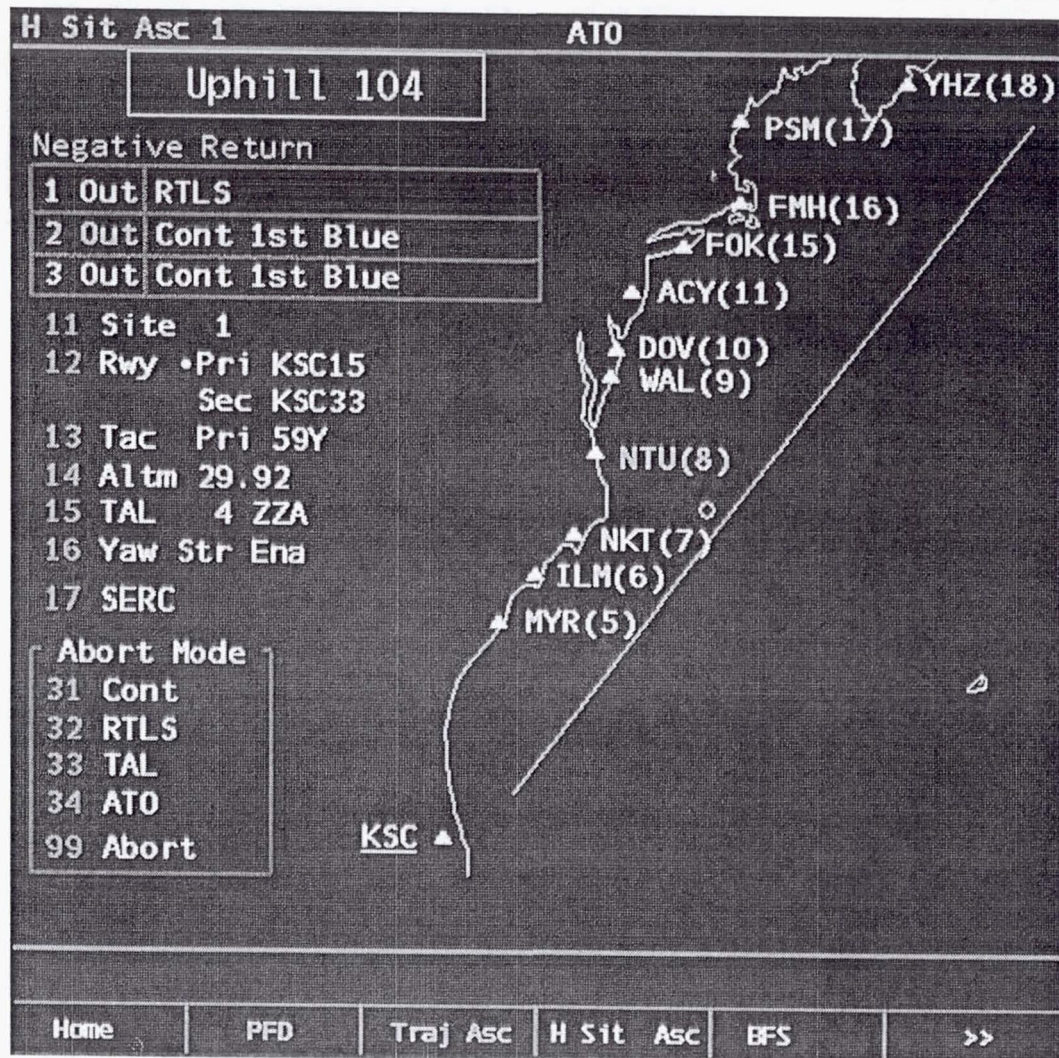


1011/050/		HORIZ SIT			1 217/06:22:56			
PTI	INH 1	ALTM			000/00:01:33			
INDEX	0	9	29.92		NAV DELTA			
40 TAL	SITE	4			ΔX 10			
41 RTLS	SITE	1			[ ] 0			
PRI	KSC15	3			ΔY 11			
SEC	KSC33	4*			[ ] 0			
TAC-	59	5			ΔZ 12			
GPS	FOM	RA			[ ] 0			
	1	46			ΔX 13			
TAEM	TGT			[ ] 0				
G/N	OVHD	6			ΔY 14			
HSI					[ ] 0			
NEP	7			ΔZ 15				
AIM	NOM	8	Δ		[ ] 0			
S/B	NOM	39			LOAD 16			
NAV	RESID	RATIO	AUT	INH	FOR	TAC1	0TAC2	0TAC3
TAC	AZ		19	20*	21			0
	RNG							
GPS			42	43*	44	DES 31	DES 32	DES 33
DRAG	H		22*	23	24	ABS 34	DELTA 35*	
ADTA	H		25	26*	27	GPS RN	AZ	
ADTA	TO G/C		28	29*	30	AIF_G	47	48* 49 H



# CAU Ascent Horizontal Situation

## with Shuttle Abort Flight Management Application



# Legacy Entry Horizontal Situation Display

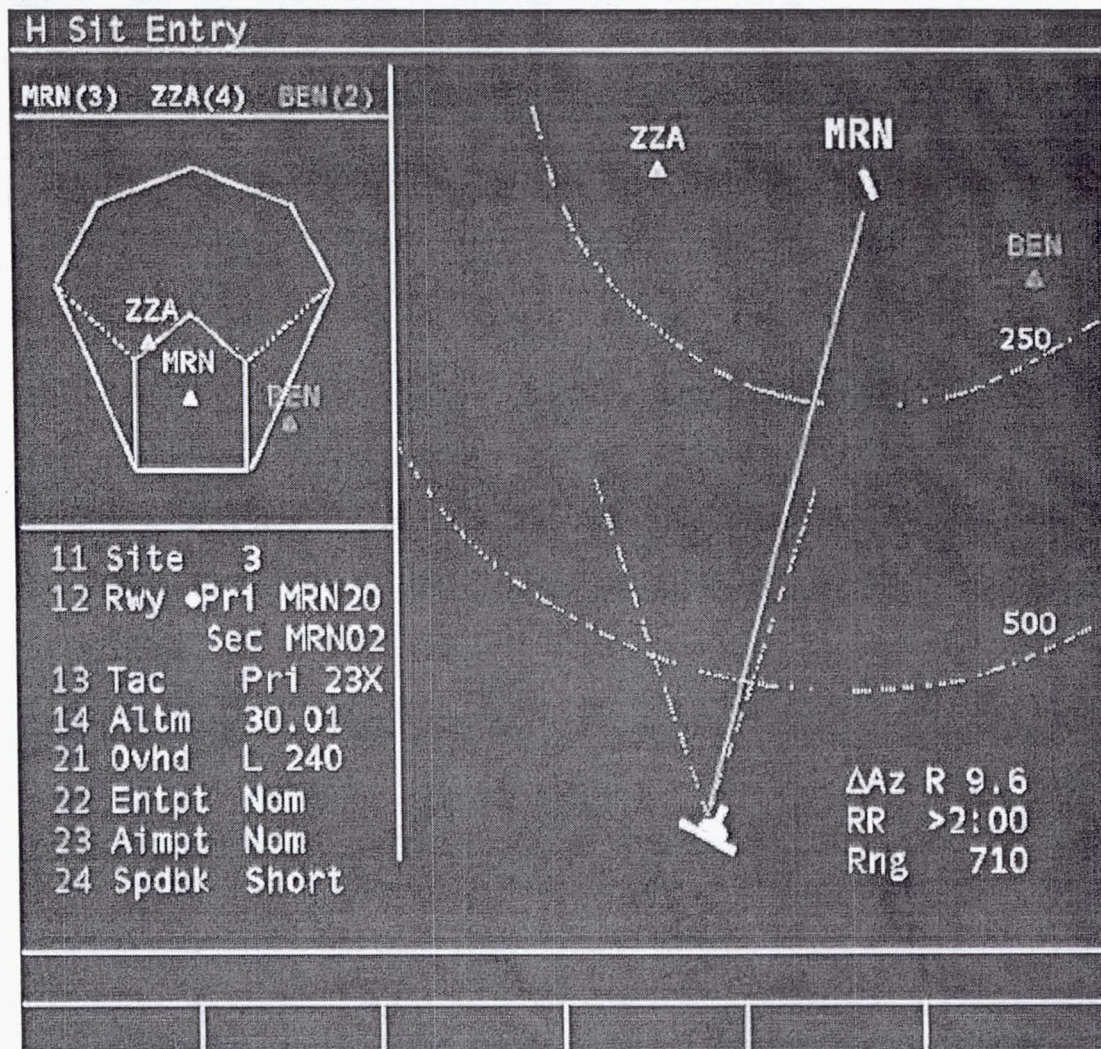


```

3041/050/          HORIZ SIT          2 010/20:00:41
PTI INH 1          ALTM                000/00:16:27
INDEX 0           9 29.92              NAV DELTA
                                         ΔX 10
                                         [ ] 0
41 LAND SITE 1    ΔY 11
PRI KSC15       3% [ ] 0
SEC KSC33       4    ΔZ 12
TAC- 59         5    [ ] 0
GPS FOM        RA   ΔX 13
1              46   [ ] 0
TAEM TGT       ΔY 14
GEN L OVHD 6   [ ] 0
HSI L          [ ] 0
NEP           7    ΔZ 15
AIM NOM 8     [ ] 0
S/B NOM 39    1.4 Δ
                                         LOAD 16
                                         18 ΔT [ ] 0.00
NAV RESID RATIO AUT INH FOR TAC1- 59 TAC2- 59 TAC3- 59
TAC AZ [ ] [ ] [ ] 19 20% 21 [ ] [ ] [ ] M M M
RNG [ ] [ ] [ ] [ ] [ ] [ ] M M M
GPS + 1.19V 0.4 42 43% 44 DES 31 DES 32 DES 33
DRAG H+ 947 0.0 22% 23 24 ABS 34 DELTA 35%
ADTA H [ ] [ ] [ ] 25 26% 27 GPS RN- 0.1 AZ+ 0.01
ADTA TO GFC 28 29% 30 AIF_G 47 48% 49 H193.0
    
```



# CAU Entry Horizontal Situation Display



# The CAU Safety Payback

Decisions and actions are more timely and accurate

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- Improved crew interface for display navigation and vehicle command and control
  - Execute commands from any display via the existing keyboards
  - Consolidate information from / commanding to multiple sources on single display
  - Fewer keystrokes, less rote memorization, and better encoding of display parameters
  - New mobile scratchpad and improved keyboard
  - Generate multi-color graphics and logical information & command groupings on any display format

