ISHM Decision Analysis Tool

IDAT

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Mission

Develop and provide a demonstration of an operations concept for assisting a spacecraft crew in making informed optimal decisions in the face of uncertainty.

Crew = on-board crew
= ground-based crew

Uncertainty = uncertain cause
= variable context

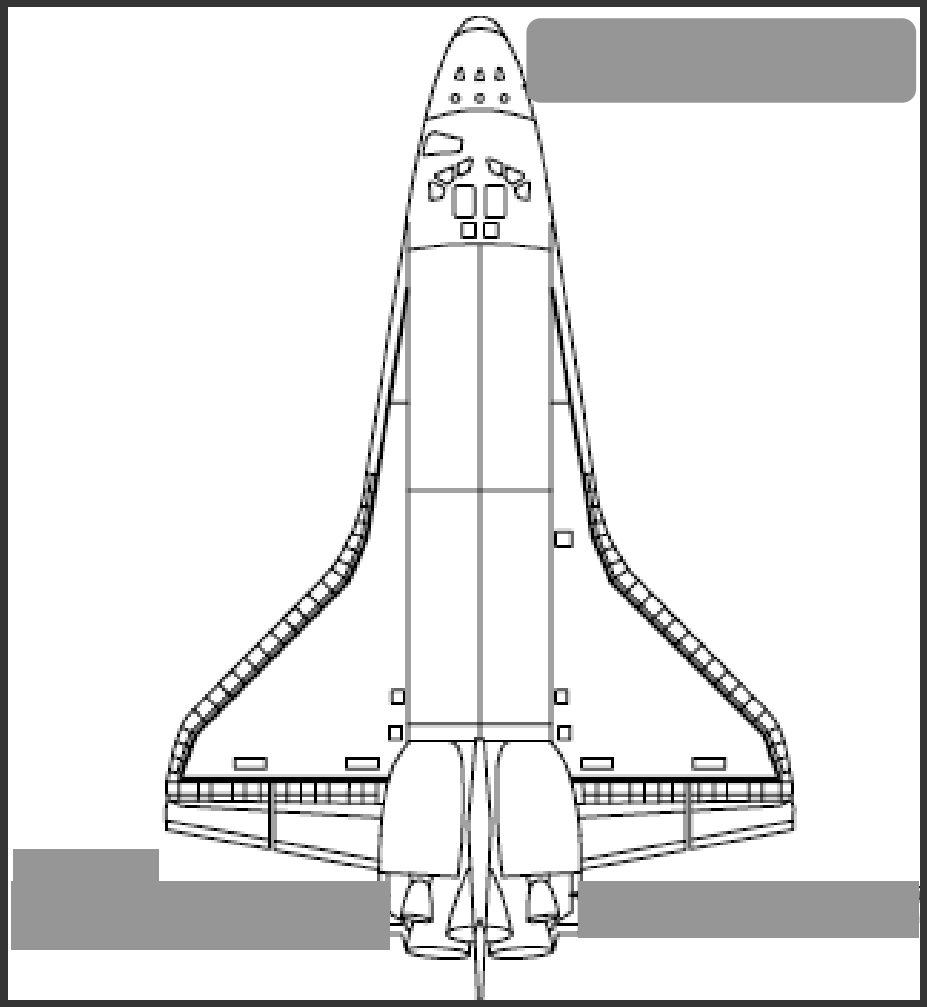
Agenda

- Domain
- Current State of Practice
- IDAT Tool
  - Interaction Overview
  - Subsystem Details
- Future Work
- Scenario
- Demo

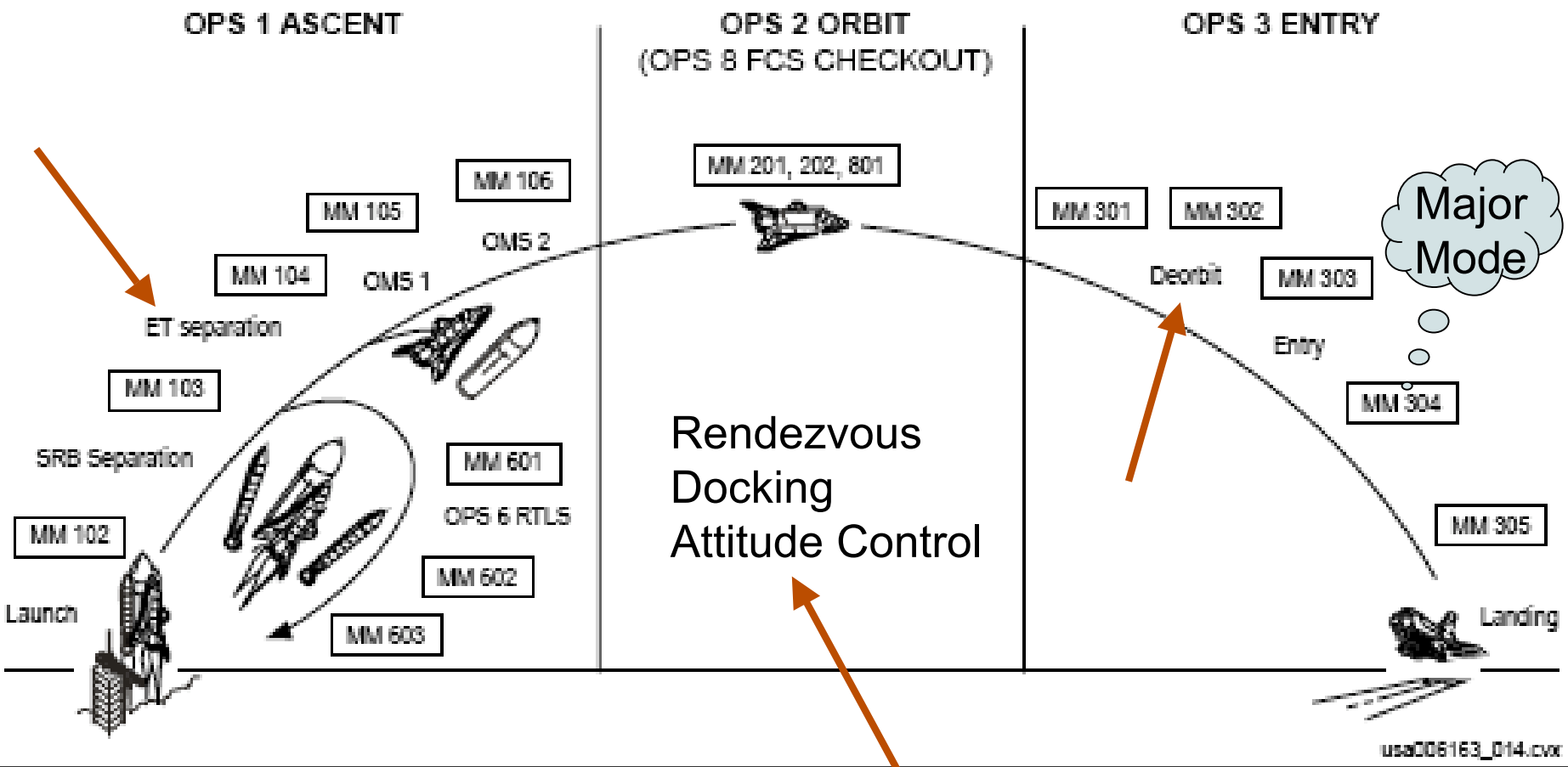
Domain

Reaction Control System (RCS)

- Rotational movement
  - Attitude control
- Translational movement
  - Velocity change
- Used alone or with MPS or OMS
- Minimum number jets required
- Hypergolic propellants

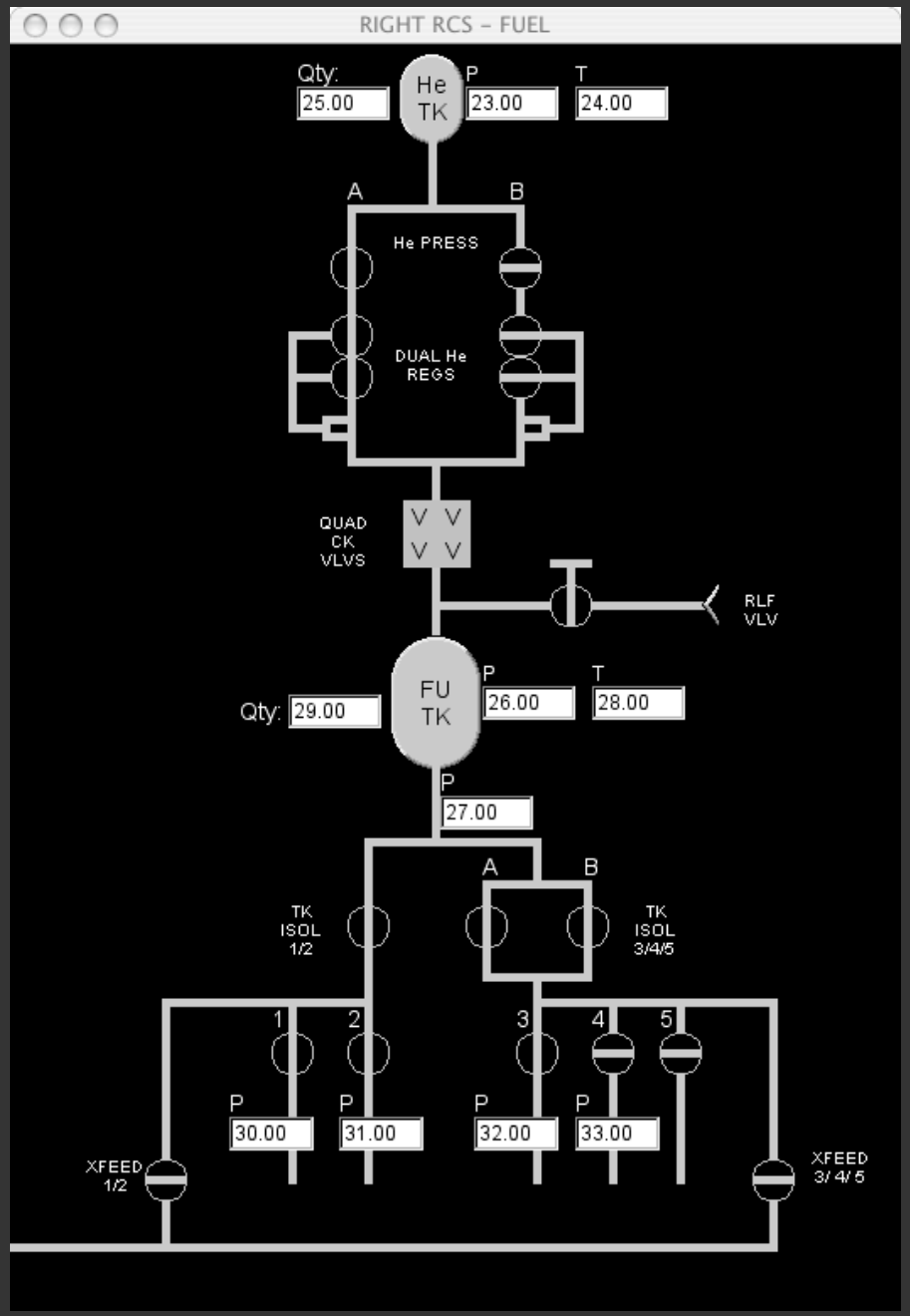


Operational Sequence



Major Mode

Rendezvous
Docking
Attitude Control


RIGHT RCS – FUEL
Qty:
25.00
He
TK
P
23.00
T
24.00
A
B
He PRESS
DUAL He
REGS
QUAD
CK
VLVS
V V
V V
RLF
VLV
Qty:
29.00
FU
TK
P
26.00
T
28.00
P
27.00
A
B
TK
ISOL
1/2
TK
ISOL
3/4/5
1
2
3
4
5
P
30.00
P
31.00
P
32.00
P
33.00
XFEED
1/2
XFEED
3/ 4/ 5

State of Practice

1031/ /019 GNC SYS SUMM 2 5 000/00:03:34
BFS 000/00:00:00

OMS AFT QTY	L	R
OXID	30.1	30.1
FU	30.1	30.1
FU INJ T	79	79

RCS		OXID	FU	JET FAIL	ISOL VLV
FWD	HE P	3245	3398		
	TK P	267	271		
	QTY	96	96		
MANF	1 P	268	269		
	2 P	267	270		
	3 P	266	270		
	4 P	267	272		
	5				
AFT	HE P	3408	3432		
L	TK P	270	267		
	QTY	1	100		
MANF	1 P	268	260		
	2 P	270	278		
	3 P	268	270		
	4 P	266	266		
	5				

OMS	L	R
TK P HE	3700	3730
OXID	282	280
FU	280	277
N2 TK P	2190	2180
REG P	326	329
P VLV	OP	OP
ENG IN P		
OXID	280	281
FU	277	280
VLV 1	- 2	- 2
2	0	0

		OXID	FU	JET FAIL	ISOL VLV
	HE P	3400	3408		
R	TK P	266	269		
	QTY	100	100		
	1 P	268	266		
	2 P	266	272		
	3 P	272	270		
	4 P	268	264		
	5				

State of Practice

```
1031/023/                    RCS                    2 000/00:03:34
                                                      000/00:00:00
RCS FWD 1*     PRI  JET     OMS PRESS ENA
      L 2   4 FAIL LIM 2     L OMS 5      OMS⇒RCS QTY
      R 3                    R OMS 6       L  0.00
                               OFF 7*      R  0.00
```

JET	FAIL	DES INH	JET DES	PTY
F1L		8	9	2
3L		10	11	1
Y 2R		12	13	2
4R		14	15	1
F1U		16	17	2
3U		18	19	1
Z 2U		20	21	3
F1D		22	23	2
3D		24	25	1
2D		26	27	2
4D		28	29	1
F1F		30	31	1
X 3F		32	33	3
2F		34	35	2
F5L		36	37	
V 5R		38	39	

	OXID	FU
HE P	3256	3392
PRPLT TK P	267	271
T	70	70
QTY	96	96
MANF P 1	268	269
2	267	270
3	266	270
4	267	272
MANF VLVS	STAT	OVRD
1	OP	40
2	OP	41
3	OP	42
4	OP	43
5	OP	44
XFEED P		
JET RESET 45		

Problem

- Busy
- Many displays available
- Massive amounts of cryptic data
- Repetitive, usually nothing breaks
- Changes are subtle
- Notification of anomaly is subtle
- Fatigue, decreased vigilance, complacency

Possible Solutions

- Task-oriented display redesign
- Automate

Possible Solutions

- Task-oriented display redesign
- Automation problems
  - Complex systems
  - Complex interaction of components
  - Model fidelity
  - Sensor limitations
  - OOTLF (Out of the loop familiarity)

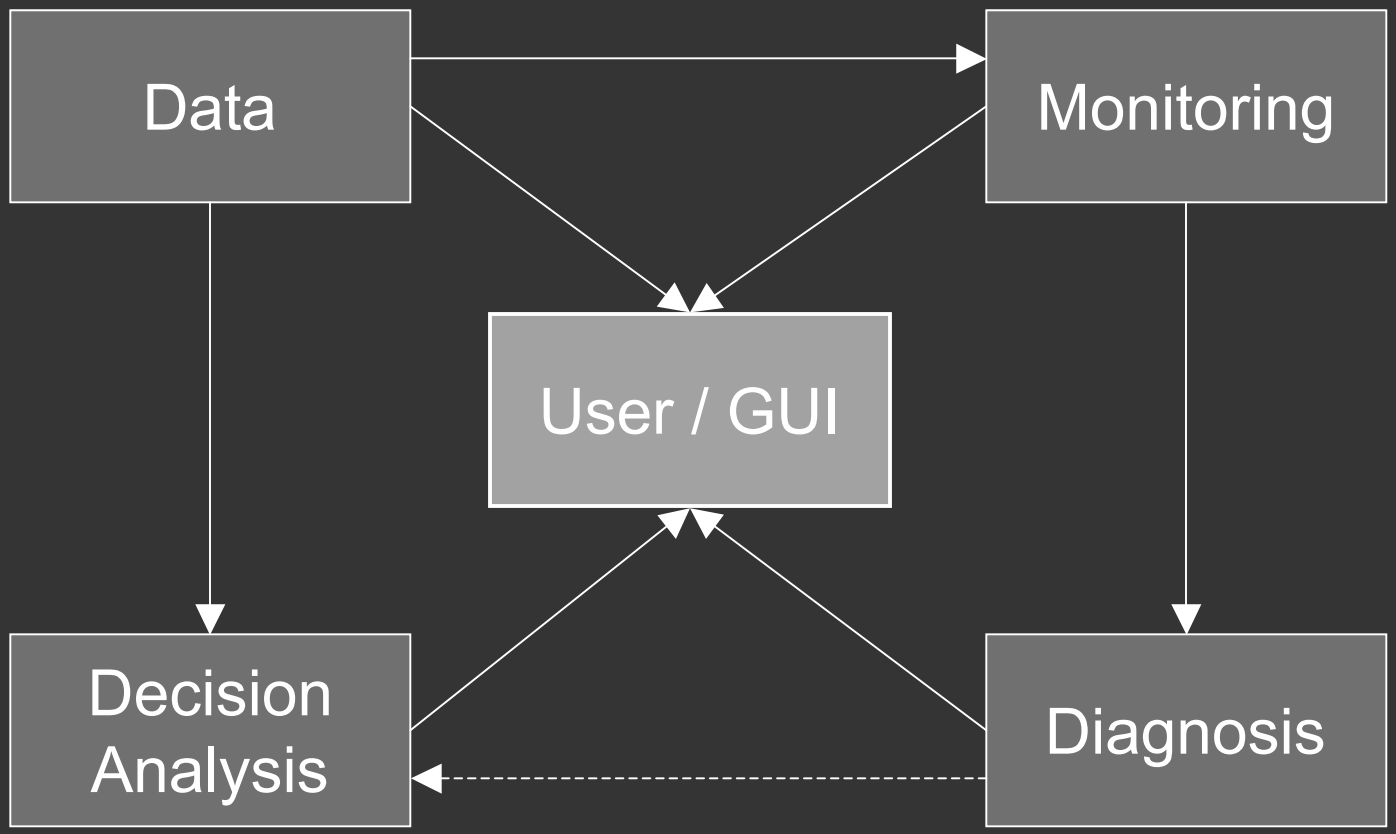
Possible Solutions

- Task-oriented display redesign
- Automation problems
  - Complex systems
  - Complex interaction of components
  - Model fidelity
  - Sensor limitations
  - OOTLF (Out of the loop familiarity)
- Coordinate automation with human participation

IDAT

- Operational concept in the embodiment of a tool
- Decision support tool that works in tandem with crew
- Assists crew with uncertain cause or variable context
- Provides germane information

IDAT Prototype Overview



State of Practice

1031/ /019 GNC SYS SUMM 2 5 000/00:03:34
BFS 000/00:00:00

OMS AFT QTY	L	R
OXID	30.1	30.1
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VLV 1 -	2	- 2
2	0	0

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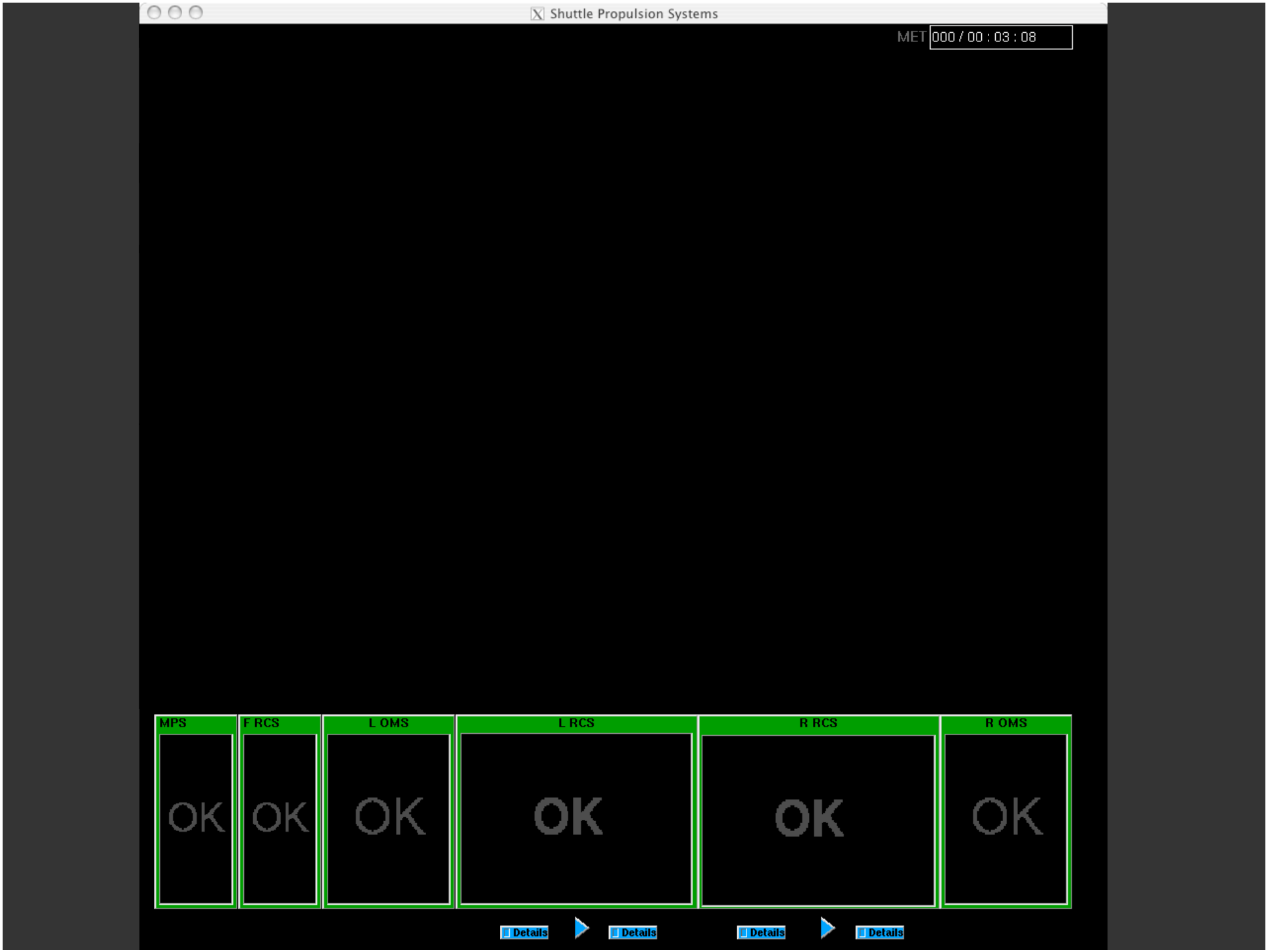
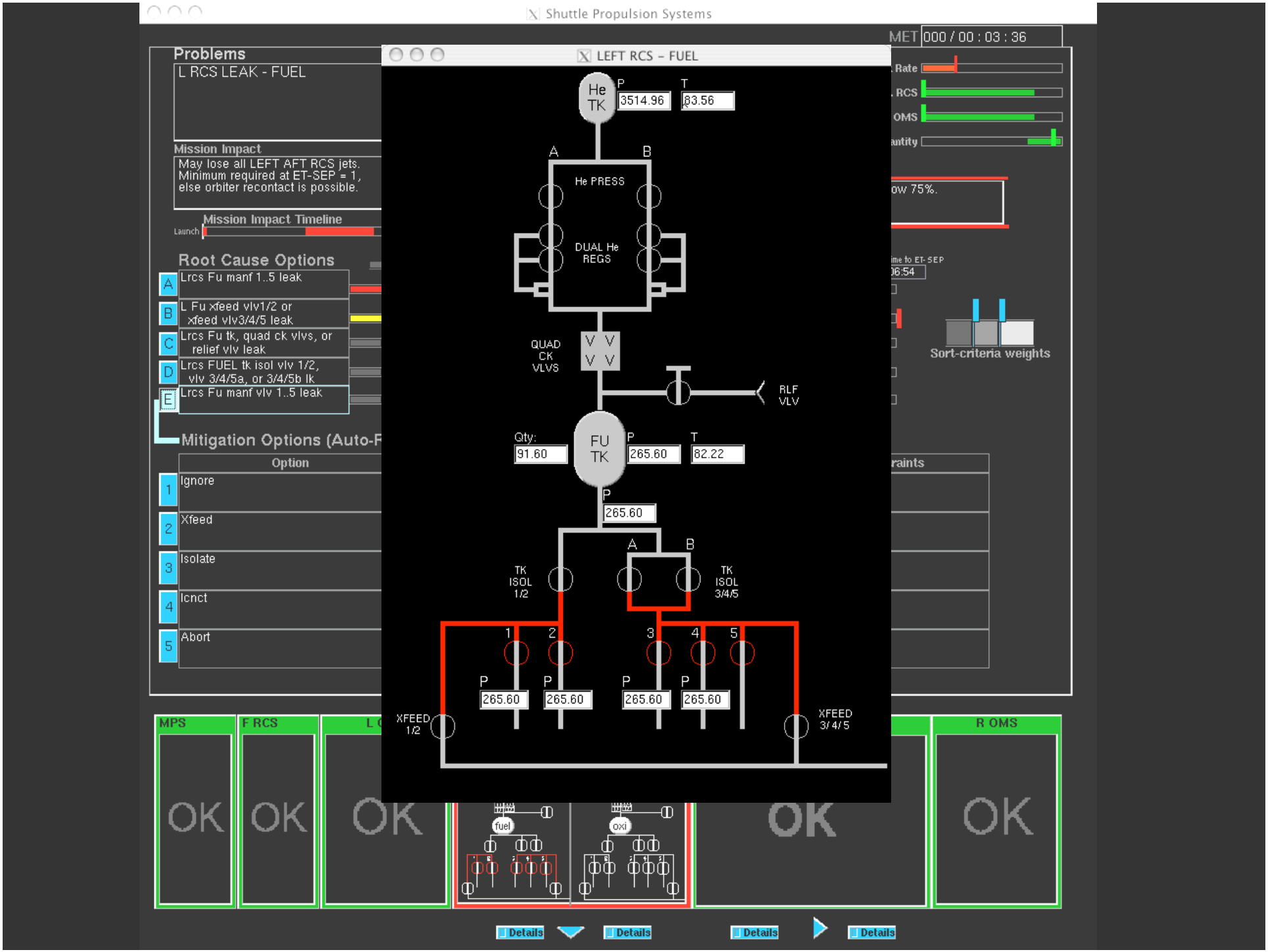
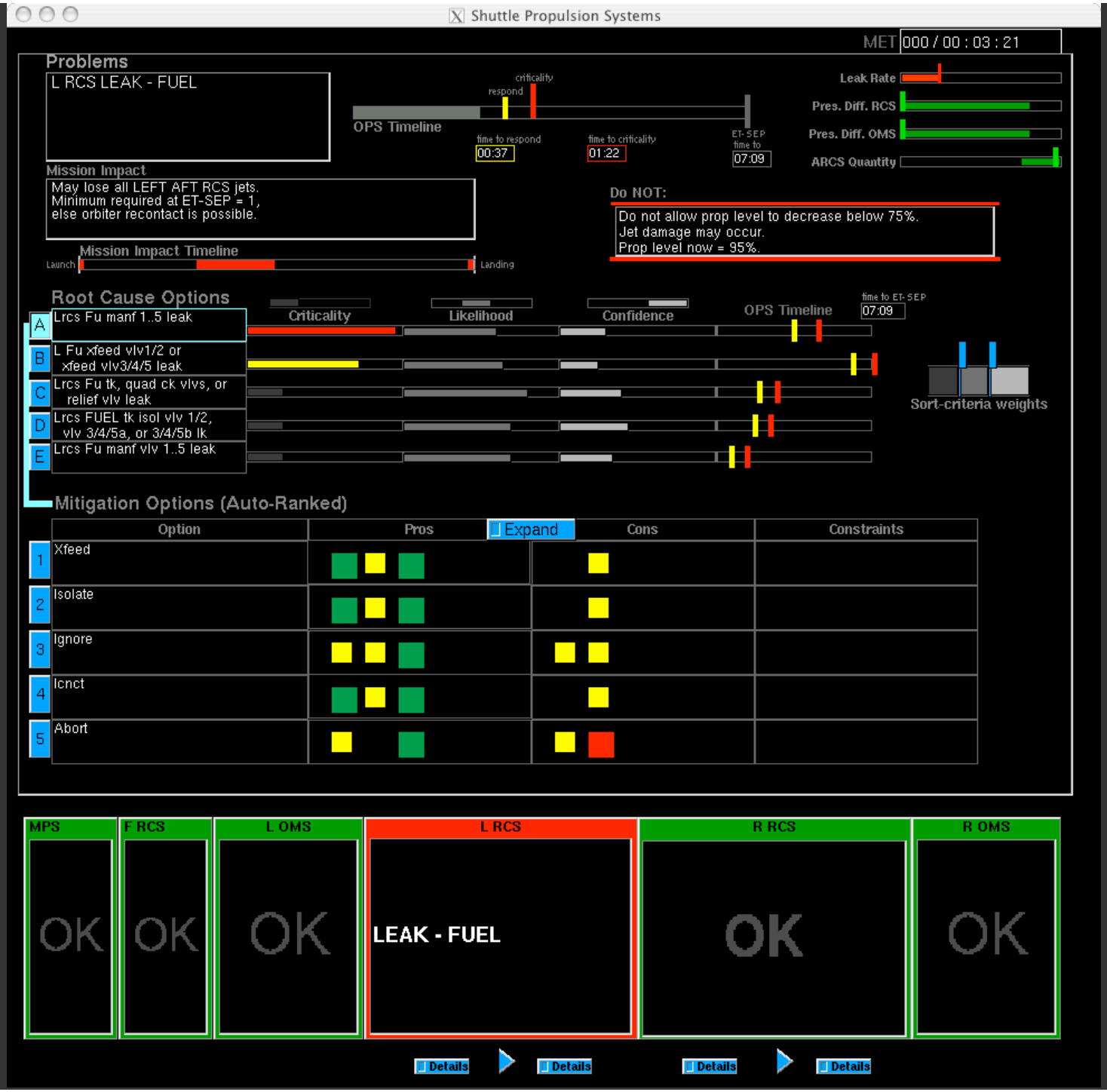
5				


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 08
MPS
OK
F RCS
OK
L OMS
OK
L RCS
OK
R RCS
OK
R OMS
OK
Details
Details
Details
Details


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 36
Problems
L RCS LEAK - FUEL
Mission Impact
May lose all LEFT AFT RCS jets. Minimum required at ET-SEP = 1, else orbiter recontact is possible.
Mission Impact Timeline
Launch
Root Cause Options
A Lrcs Fu manf 1..5 leak
B L Fu xfeed vlv1/2 or xfeed vlv3/4/5 leak
C Lrcs Fu tk, quad ck vlvs, or relief vlv leak
D Lrcs FUEL tk isol vlv 1/2, vlv 3/4/5a, or 3/4/5b lk
E Lrcs Fu manf vlv 1..5 leak
Mitigation Options (Auto-F
Option
1 Ignore
2 Xfeed
3 Isolate
4 Icnct
5 Abort
Sort-criteria weights
LEFT RCS - FUEL
He TK
P 3514.96
T 83.56
A
B
He PRESS
DUAL He REGS
QUAD CK VLVS
V V
V V
RLF VLV
Qty: 91.60
FU TK
P 265.60
T 82.22
P 265.60
TK ISOL 1/2
TK ISOL 3/4/5
1 2 3 4 5
P 265.60
XFEED 1/2
XFEED 3/4/5
MPS
F RCS
R OMS
OK
fuel
oxi
Details


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 21
Problems
L RCS LEAK - FUEL
OPS Timeline
criticality
respond
time to respond
00:37
time to criticality
01:22
ET-SEP
time to
07:09
Leak Rate
Pres. Diff. RCS
Pres. Diff. OMS
ARCS Quantity
Mission Impact
May lose all LEFT AFT RCS jets.
Minimum required at ET-SEP = 1,
else orbiter recontact is possible.
Do NOT:
Do not allow prop level to decrease below 75%.
Jet damage may occur.
Prop level now = 95%.
Mission Impact Timeline
Launch
Landing
Root Cause Options
Criticality
Likelihood
Confidence
OPS Timeline
time to ET-SEP
07:09
A Lrcs Fu manf 1..5 leak
B L Fu xfeed vlv1/2 or xfeed vlv3/4/5 leak
C Lrcs Fu tk, quad ck vlvs, or relief vlv leak
D Lrcs FUEL tk isol vlv 1/2, vlv 3/4/5a, or 3/4/5b lk
E Lrcs Fu manf vlv 1..5 leak
Sort-criteria weights
Mitigation Options (Auto-Ranked)
Option
Pros
Expand
Cons
Constraints
1 Xfeed
2 Isolate
3 Ignore
4 Icnct
5 Abort
MPS
OK
F RCS
OK
L OMS
OK
L RCS
LEAK - FUEL
R RCS
OK
R OMS
OK
Details
Details
Details
Details

Shuttle Propulsion Systems

MET 000 / 00 : 03 : 22

Problems

L RCS LEAK - FUEL

OPS Timeline

respond

criticality

time to respond 00:36

time to criticality 01:21

ET-SEP time to 07:08

Leak Rate

Pres. Diff. RCS

Pres. Diff. OMS

ARCS Quantity

Mission Impact

May lose all LEFT AFT RCS jets.
Minimum required at ET-SEP = 1,
else orbiter recontact is possible.

Do NOT:

Do not allow prop level to decrease below 75%.
Jet damage may occur.
Prop level now = 95%.

Mission Impact Timeline

Launch — Landing

Root Cause Options

		Criticality	Likelihood	Confidence	OPS Timeline (time to ET-SEP 07:08)
A	Lrcs Fu manf 1..5 leak				
B	L Fu xfeed vlv1/2 or xfeed vlv3/4/5 leak				
C	Lrcs Fu tk, quad ck vlvs, or relief vlv leak				
D	Lrcs FUEL tk isol vlv 1/2, vlv 3/4/5a, or 3/4/5b lk				
E	Lrcs Fu manf vlv 1..5 leak				

Sort-criteria weights

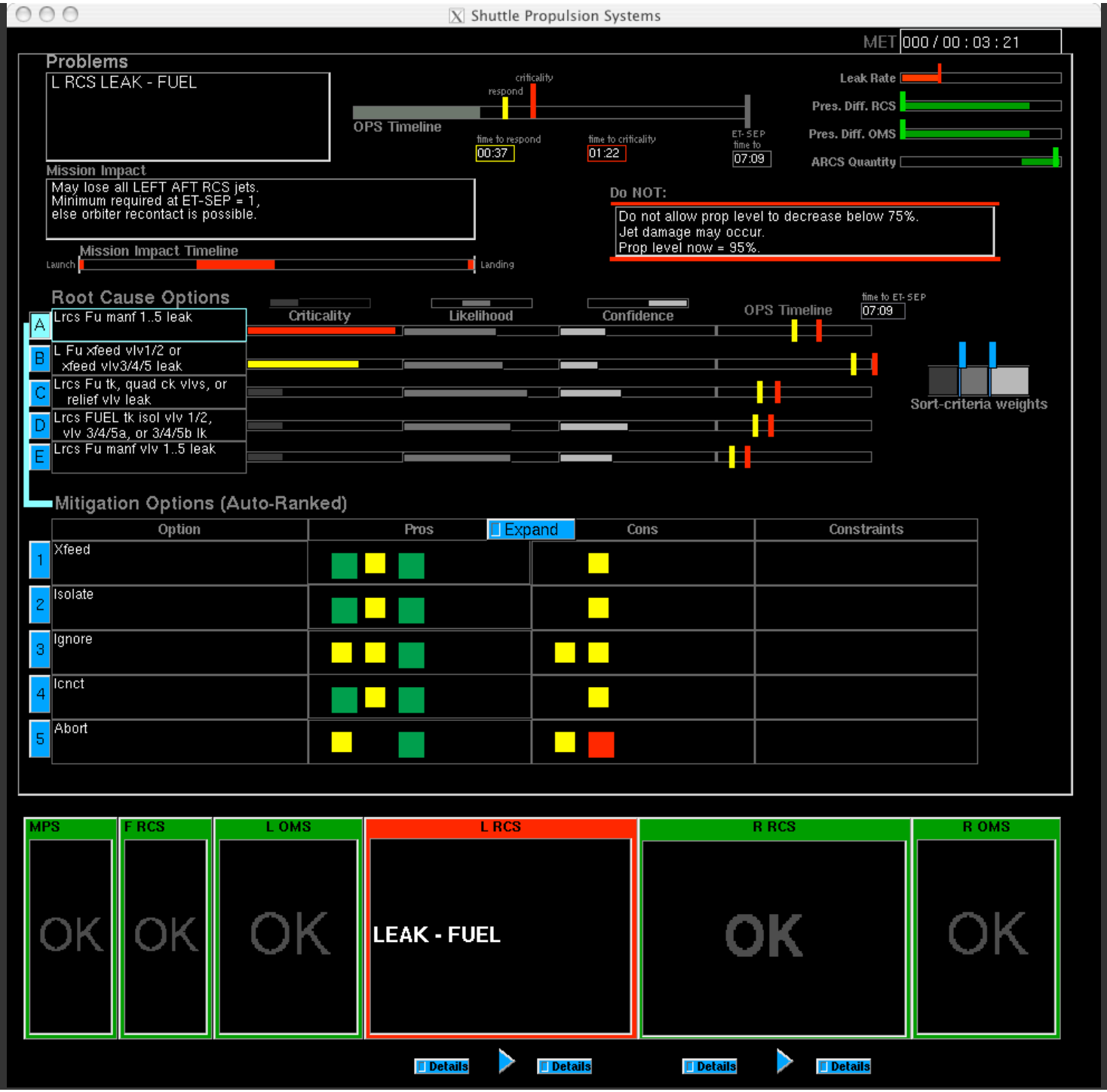
Mitigation Options (Auto-Ranked)

Expand

	Option	Pros	Cons	Constraints
1	Xfeed	Some Resources; Low crewfactor; No Damage;		
2	Isolate	Some Resources; Low crewfactor; No Damage;		
3	Ignore	No Damage;	Many Resources; No Damage; High	
4	Icnct	Some Resources; Low crewfactor; No Damage;		
5	Abort	Low crewfactor; No Damage;	Many Resources; No Damage;	

MPS	F RCS	L OMS	L RCS	R RCS	R OMS
OK	OK	OK	LEAK - FUEL	OK	OK

Details Details Details Details


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 21
Problems
L RCS LEAK - FUEL
OPS Timeline
criticality
respond
time to respond
00:37
time to criticality
01:22
ET-SEP
time to
07:09
Leak Rate
Pres. Diff. RCS
Pres. Diff. OMS
ARCS Quantity
Mission Impact
May lose all LEFT AFT RCS jets.
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Launch
Landing
Root Cause Options
Criticality
Likelihood
Confidence
OPS Timeline
time to ET-SEP
07:09
A Lrcs Fu manf 1..5 leak
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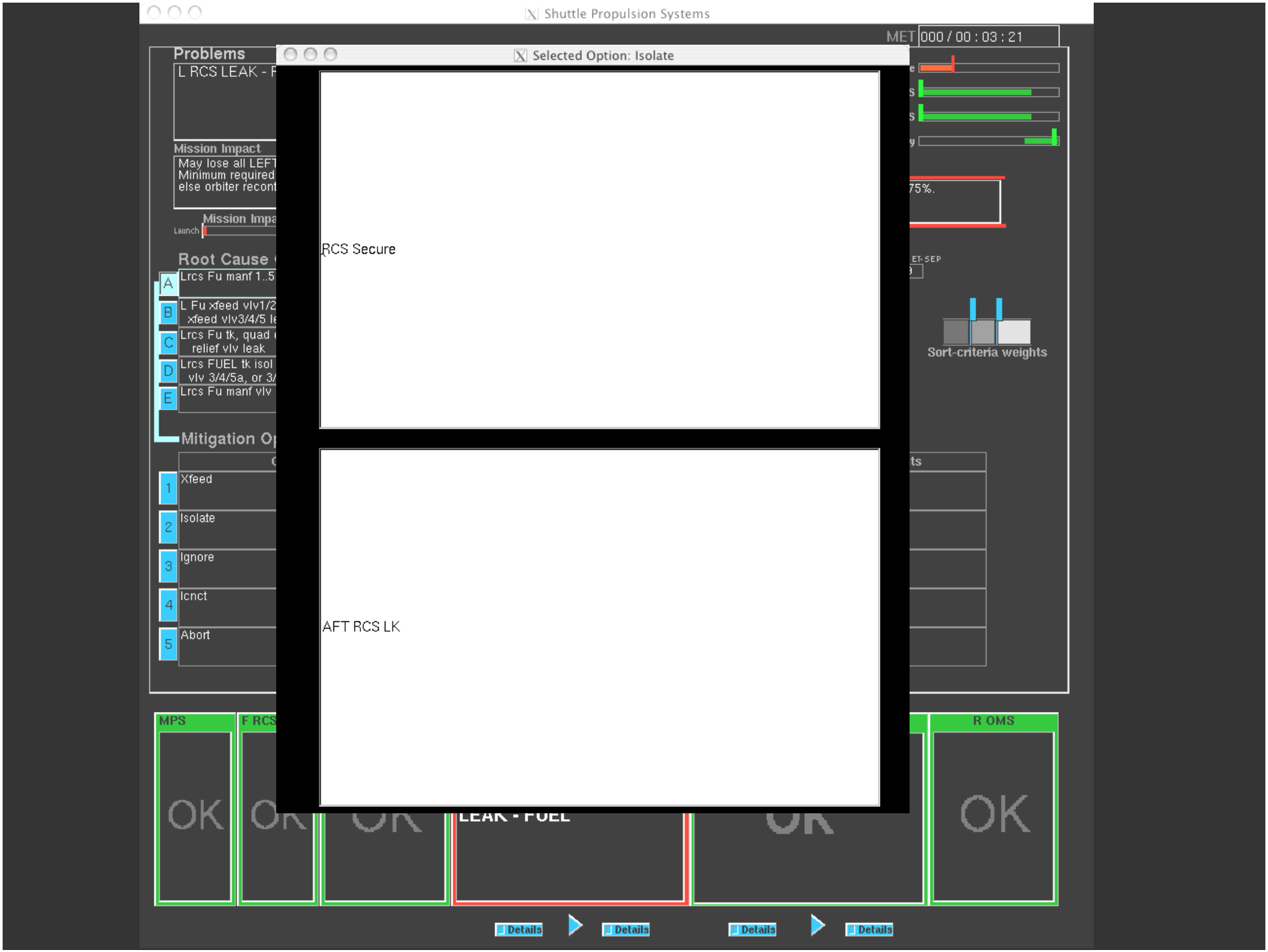
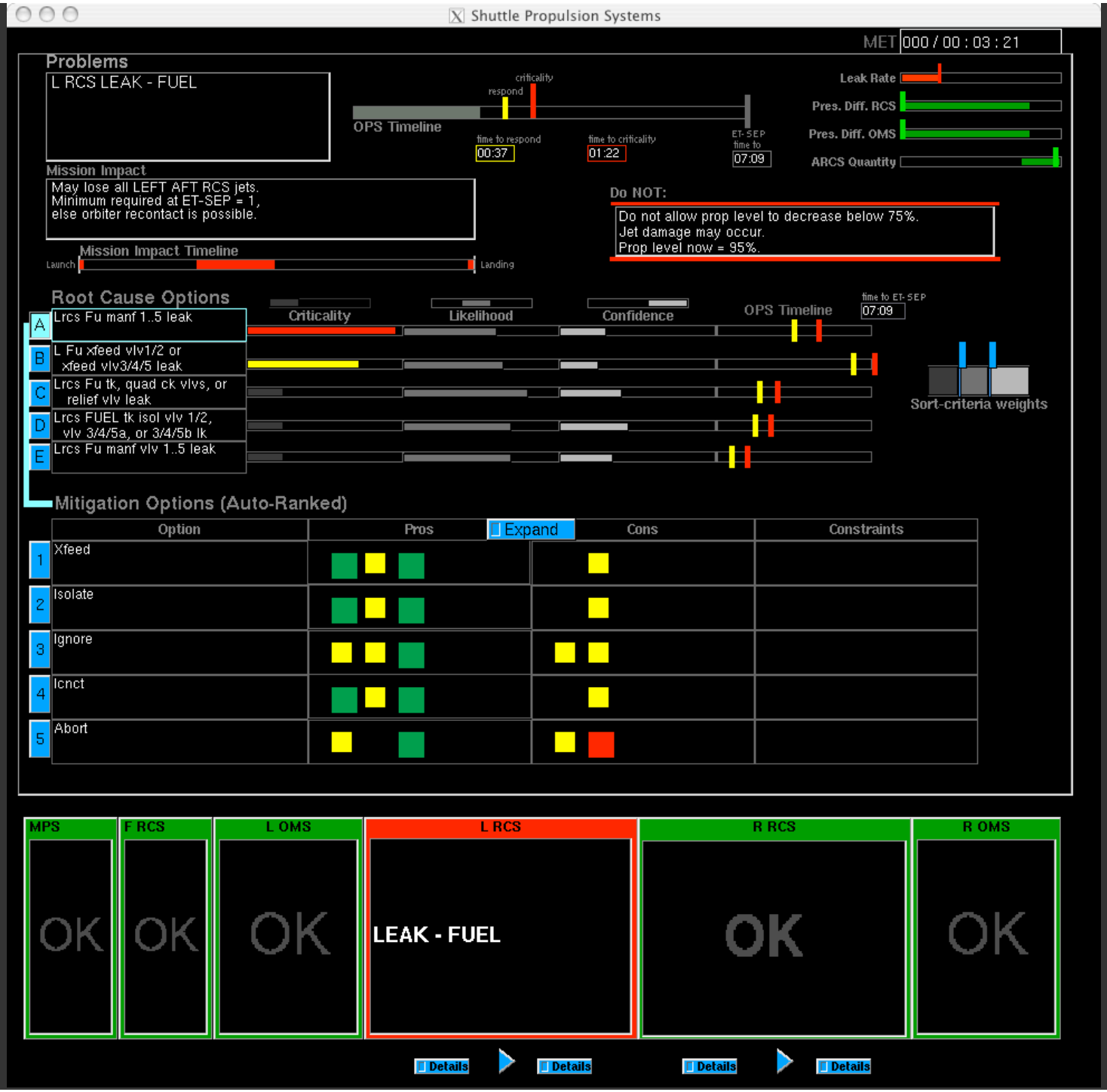
E Lrcs Fu manf vlv 1..5 leak
Sort-criteria weights
Mitigation Options (Auto-Ranked)
Option
Pros
Expand
Cons
Constraints
1 Xfeed
2 Isolate
3 Ignore
4 Icnct
5 Abort
MPS
OK
F RCS
OK
L OMS
OK
L RCS
LEAK - FUEL
R RCS
OK
R OMS
OK
Details
Details
Details
Details


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 21
Selected Option: Isolate
RCS Secure
AFT RCS LK
Problems
L RCS LEAK - F
Mission Impact
May lose all LEFT
Minimum required
else orbiter recont
Mission Impa
Launch
Root Cause
A Lrcs Fu manf 1..5
B L Fu xfeed vlv1/2
xfeed vlv3/4/5 le
C Lrcs Fu tk, quad
relief vlv leak
D Lrcs FUEL tk isol
vlv 3/4/5a, or 3/
E Lrcs Fu manf vlv
Mitigation Op
1 Xfeed
2 Isolate
3 Ignore
4 Icnct
5 Abort
75%.
ET-SEP
Sort-criteria weights
MPS
F RCS
R OMS
OK
OK
OK
LEAK - FUEL
OK
OK
Details
Details
Details
Details


Shuttle Propulsion Systems
MET 000 / 00 : 03 : 21
Problems
L RCS LEAK - FUEL
OPS Timeline
criticality
respond
time to respond
00:37
time to criticality
01:22
ET-SEP
time to
07:09
Leak Rate
Pres. Diff. RCS
Pres. Diff. OMS
ARCS Quantity
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Launch
Landing
Root Cause Options
Criticality
Likelihood
Confidence
OPS Timeline
time to ET-SEP
07:09
A Lrcs Fu manf 1..5 leak
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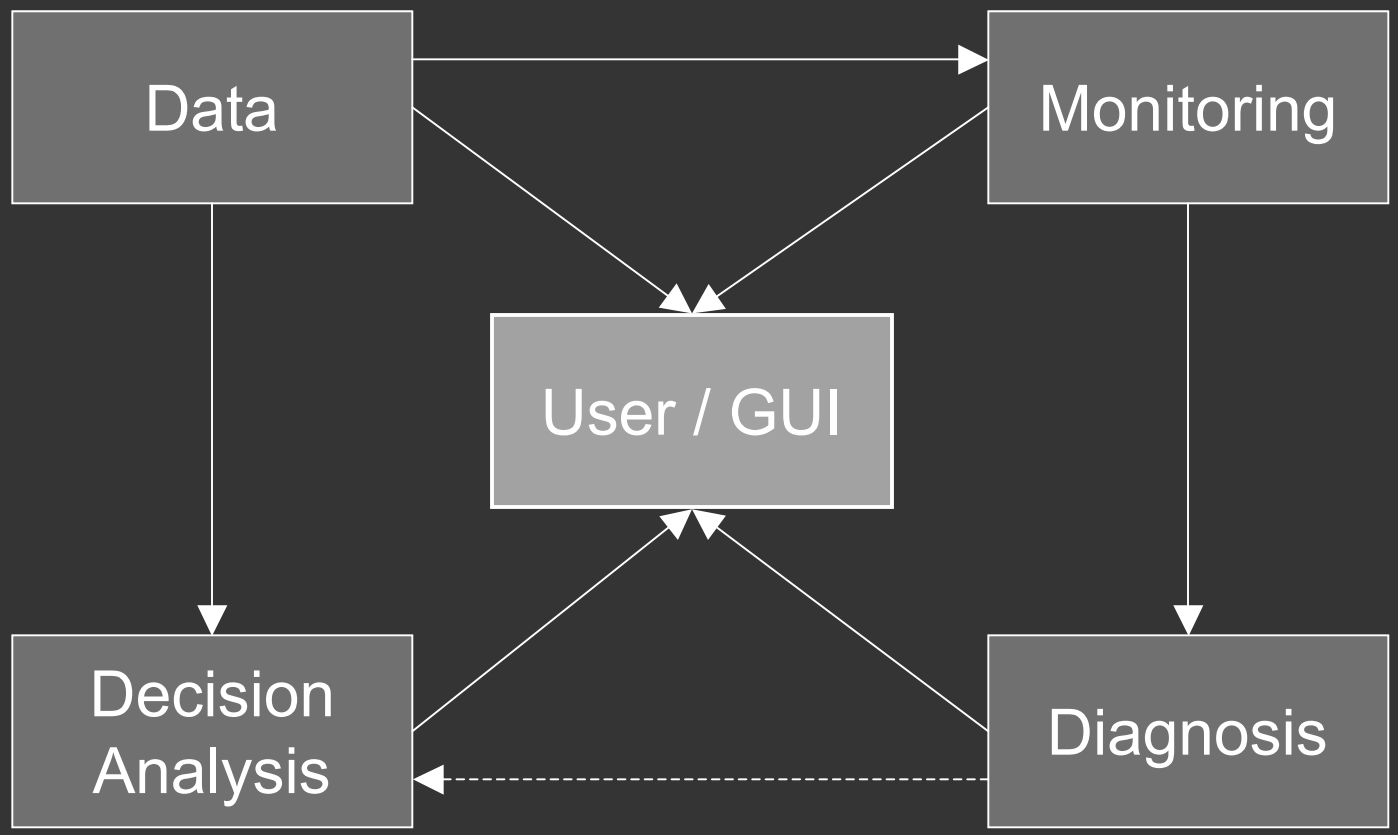
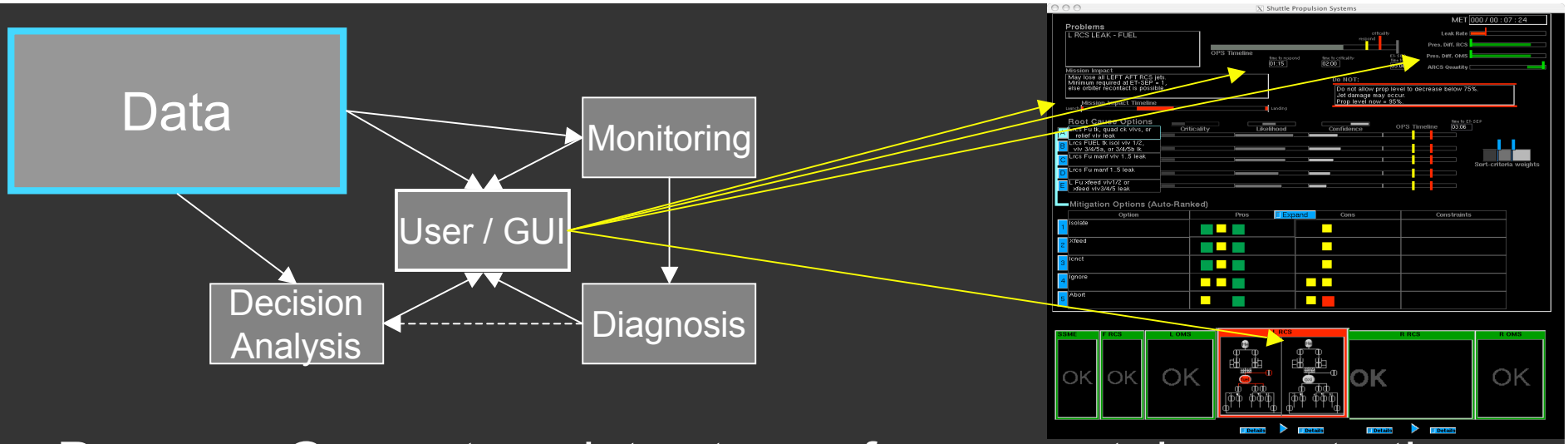
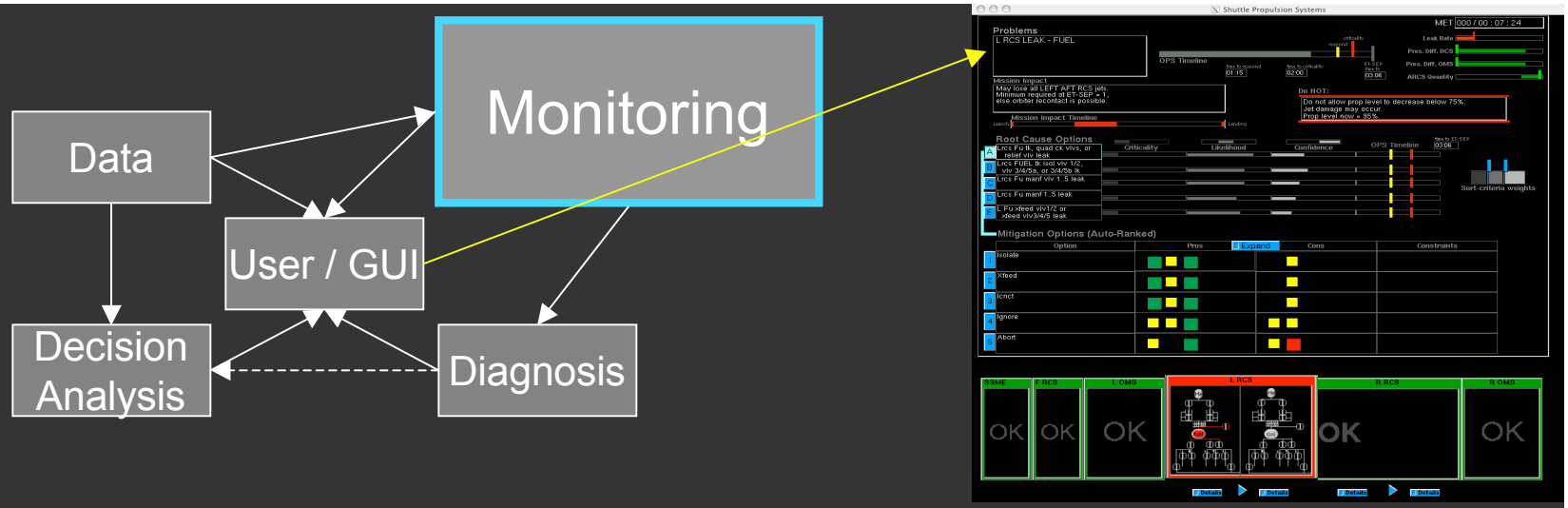
C Lrcs Fu tk, quad ck vlvs, or relief vlv leak
D Lrcs FUEL tk isol vlv 1/2, vlv 3/4/5a, or 3/4/5b lk
E Lrcs Fu manf vlv 1..5 leak
Sort-criteria weights
Mitigation Options (Auto-Ranked)
Option
Pros
Expand
Cons
Constraints
1 Xfeed
2 Isolate
3 Ignore
4 Icnct
5 Abort
MPS
OK
F RCS
OK
L OMS
OK
L RCS
LEAK - FUEL
R RCS
OK
R OMS
OK
Details
Details
Details
Details

IDAT Prototype Architecture

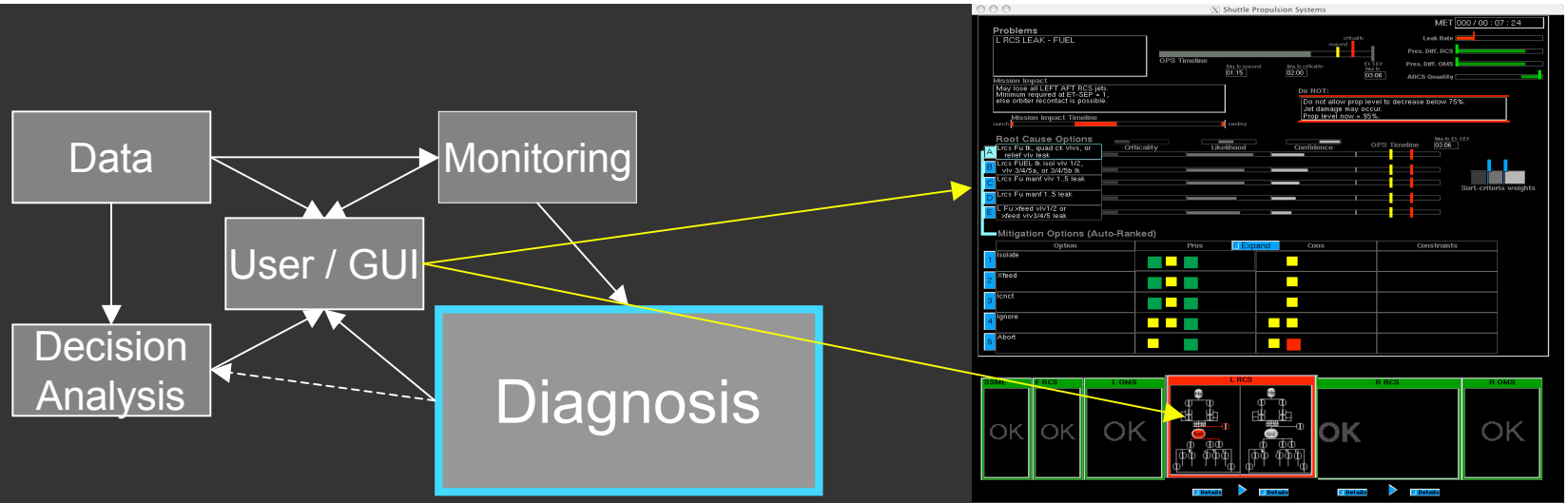




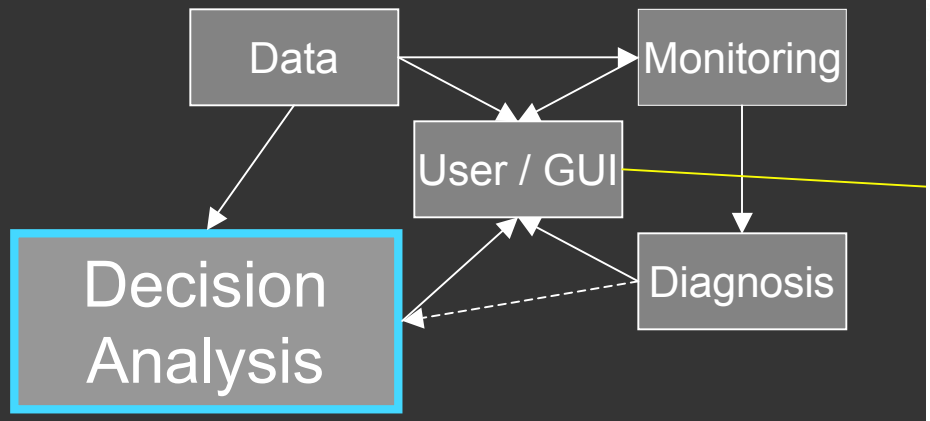
- Purpose: Generate a data stream for concept demonstration
- STS-114 data (RCS parameters, 15 minutes)
- Prototype Challenges
  - Map desired parameter to MSID
  - Multiple configurations (8)
    - Simulate {normal, secure, xfeed, partial xfeed} X {ok, leak}
    - Introduce a leak
    - Transition between configurations
- Appears on UI as:
  - Relevant cues, OPS Timeline
  - State of schematic components
  - “Mission Impact Timeline” (representative data)

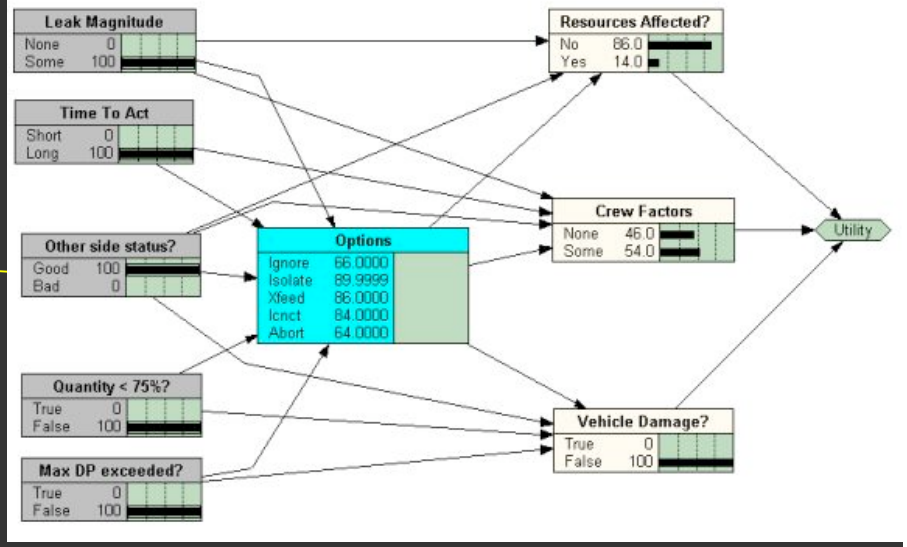


- Purpose: Monitor incoming data for anomalous behavior
- Implementation: (Substitute system) Looks for a leak, only
- Appears on UI as:
  - Causes IDAT to appear
  - “Problem” section



- Purpose: Identify root cause(es) of anomalous situation
- Implementation: (Substitute system) Hand-coded
- Appears on UI as
  - “Root Cause Options” section
    - Likelihood and confidence
    - Currently provides criticality, time to respond, and time to criticality
  - State of schematic components per root cause





- Purpose: Rank mitigation options for highest utility
- Mitigation options {ignore, isolate, xfeed, icnct, abort}
- Basic model in Netica
  - 5 inputs {leak rate, ttc, press. diff, prop. quantity, other RCS state}
  - 3 expert-knowledge nodes {resources used, vehicle damage, crew factor}
- Issues
  - Parameter optimization
  - Does not take diagnosis into account
- Appears on UI as “Mitigation Options” section:
  - Options ranked by utility
  - Pros & Cons encode expert-knowledge node values

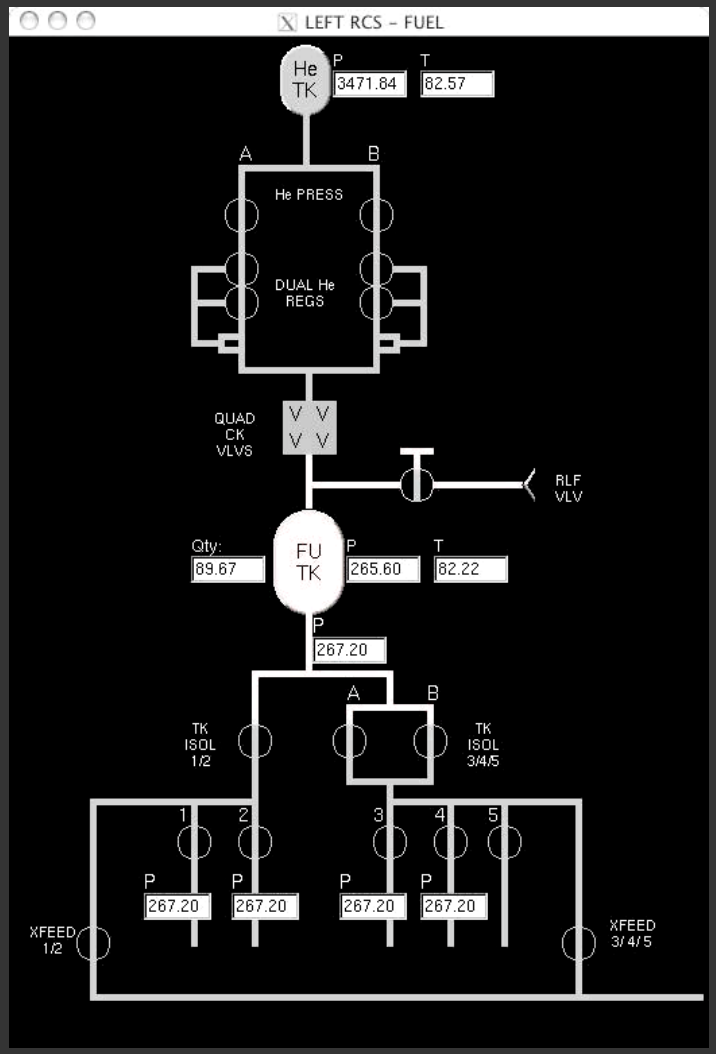
Summary

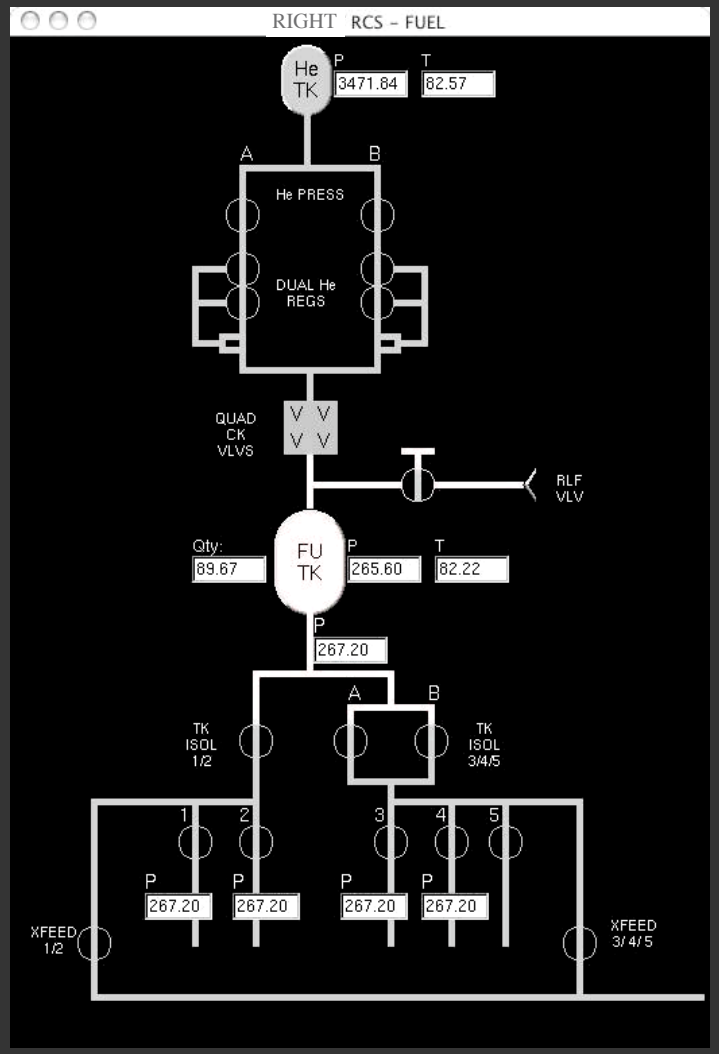
- Operational concept for C&W under uncertainty
- Prototype system that presents information to help crew
  - Resolve ambiguity of multiple root causes
  - Determine method for mitigating problem
- Evolving discussion
  - Many issues remain to be resolved
  - User involvement necessary
  - Tie it into operational concept for overall C&W

Future Work

- User Interaction
- Data System
- Diagnosis System
- Decision Support System
- Mitigation Procedures
- Human Factors (Display)
- Operations concept for C&W system

Scenario


LEFT RCS - FUEL
He TK
P
3471.84
T
82.57
A
B
He PRESS
DUAL He REGS
QUAD CK VLVS
V V
V V
RLF VLV
Qty:
89.67
FU TK
P
265.60
T
82.22
P
267.20
A
B
TK ISOL 1/2
TK ISOL 3/4/5
1
2
3
4
5
P
267.20
P
267.20
P
267.20
P
267.20
XFEED 1/2
XFEED 3/4/5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A
B
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QUAD CK VLVS
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V V
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Qty:
89.67
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265.60
T
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P
267.20
A
B
TK ISOL 1/2
TK ISOL 3/4/5
1
2
3
4
5
P
267.20
P
267.20
P
267.20
P
267.20
XFEED 1/2
XFEED 3/4/5

IDAT DEMO