Design of a Data-Driven Micro-Display for Situation Awareness in Bursty Environments

Alexandra Holloway
UC Santa Cruz – Department of Computer Science
JPL/Caltech – Human Interfaces Group

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*(when not much is happening most of the time)

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California Institute of Technology,
NASA Jet Propulsion Laboratory in Pasadena, CA
under the supervision of Caltech Institutional Review Board (IRB)

and by the President's Dissertation Year Fellowship (2014-15)

2011 Advancement to Candidacy (Computer Science)

2010 MS Computer Engineering ()

2003 BS Computer Engineering
BS Mathematics

20+ Papers published

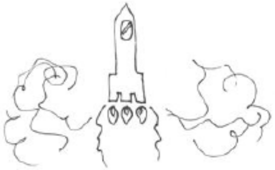
17 Co-authors

5 Classes instructor / TA

5 Fields

1 Keynote address

Interaction Design	How IxD complements and differs from user research
Complex Systems	Characteristics and examples, and why monitoring and controlling is hard
The Deep Space Network	What it is, how operators work it, and what we learn
The Postage Stamp	Intervention design, implementation, and reception
Implications	Automation, simulation, design analogy, and situation awareness advancements



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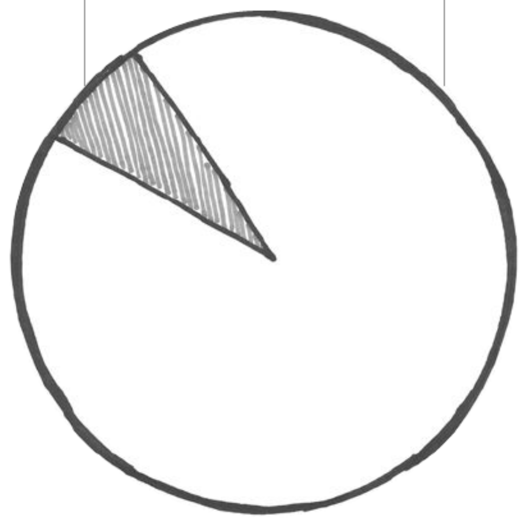
Building stuff (10%)

Prototype
Creating low- to high-fidelity prototypes to support the work



User research (90%)

Ethnography
Examining how people work within their sociotechnical system

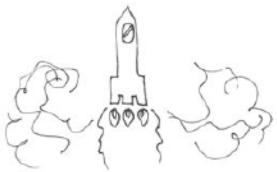
Design methods
Using design activities and techniques to elicit responses to specific inquiries

Goals for user research

1. Perceive the same things as users
2. Understand how users reason about the perceptions
3. Become adept at predicting the future state of a system, as the users do

Goals for interaction design

1. Determine who the users are and what they need to see and do
2. Expose information, not data
3. Create the way users experience the changing states of a system



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Complex systems

Partially automated

Variety of sensor sources

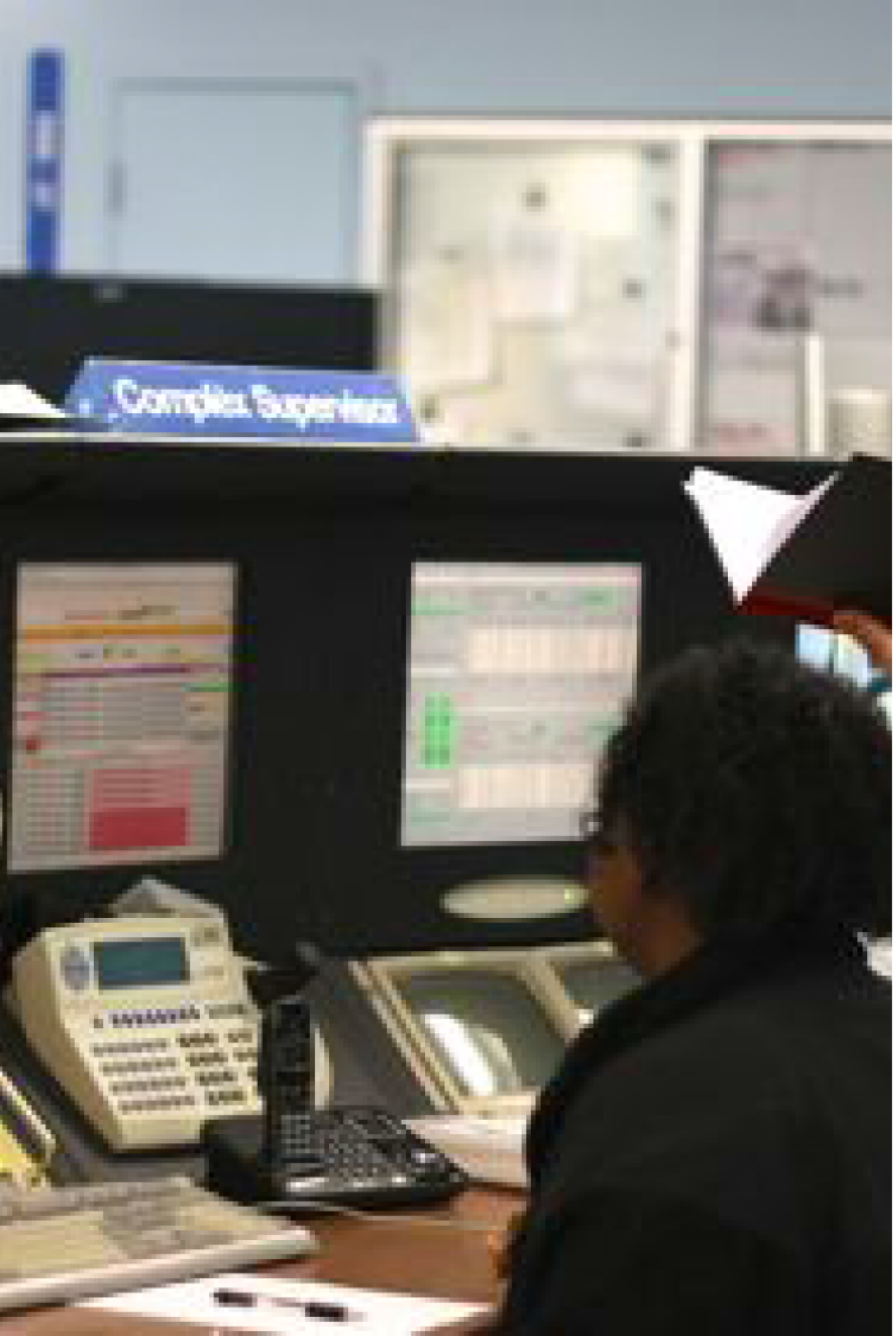
Large aggregation of hardware, software, and human behavior

Great variety of states the system can assume

Causal relationships which may be distant in time and space

Feedback loops between system variables

High stakes (error risk)



Operation

Highly complex technical tasks

Primarily physical or perceptual tasks

Required timely decision-making

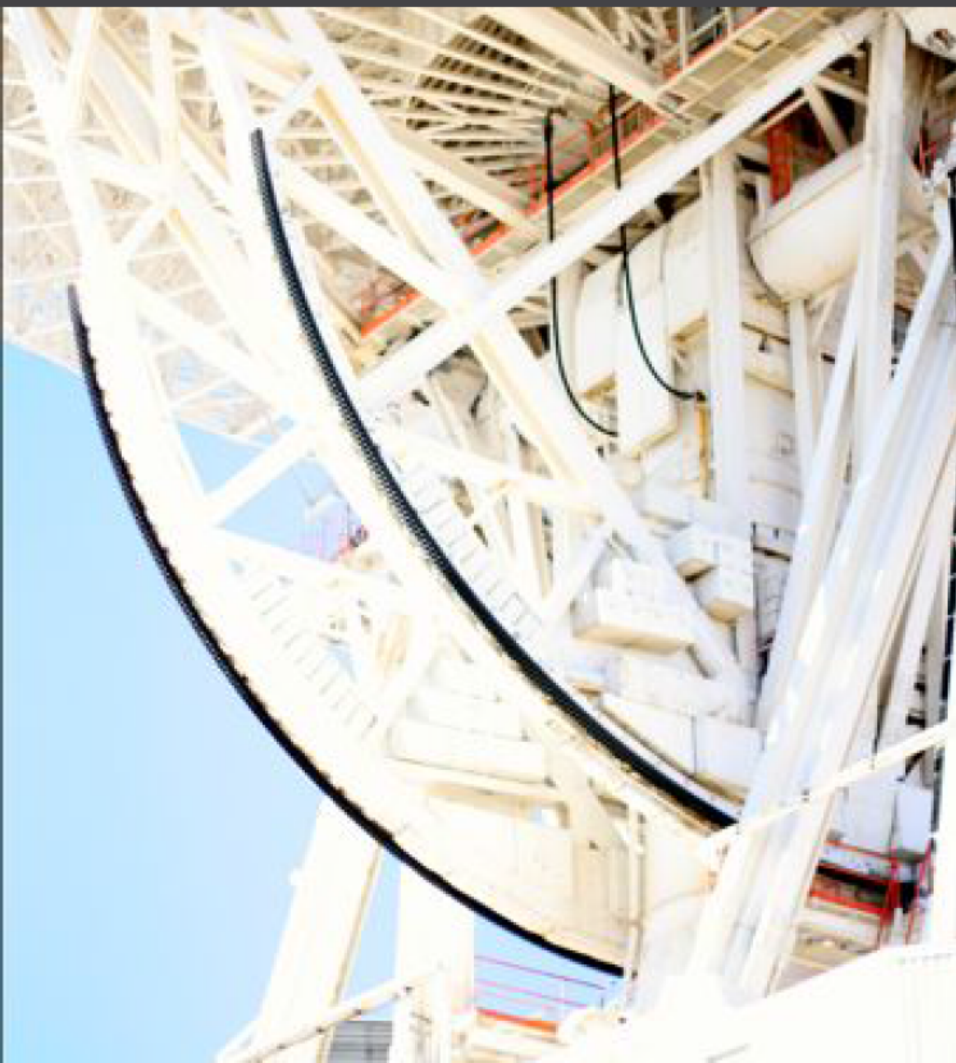
High variety of task situations

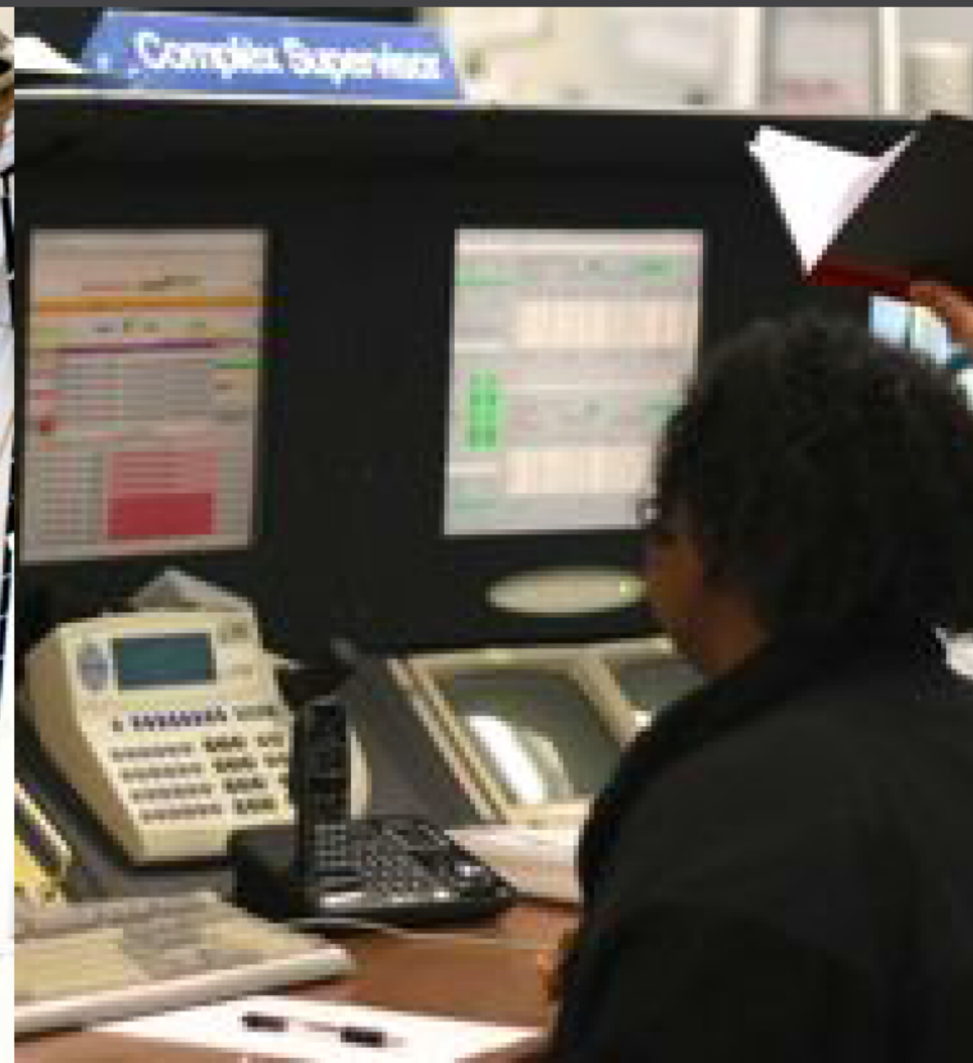
High task load

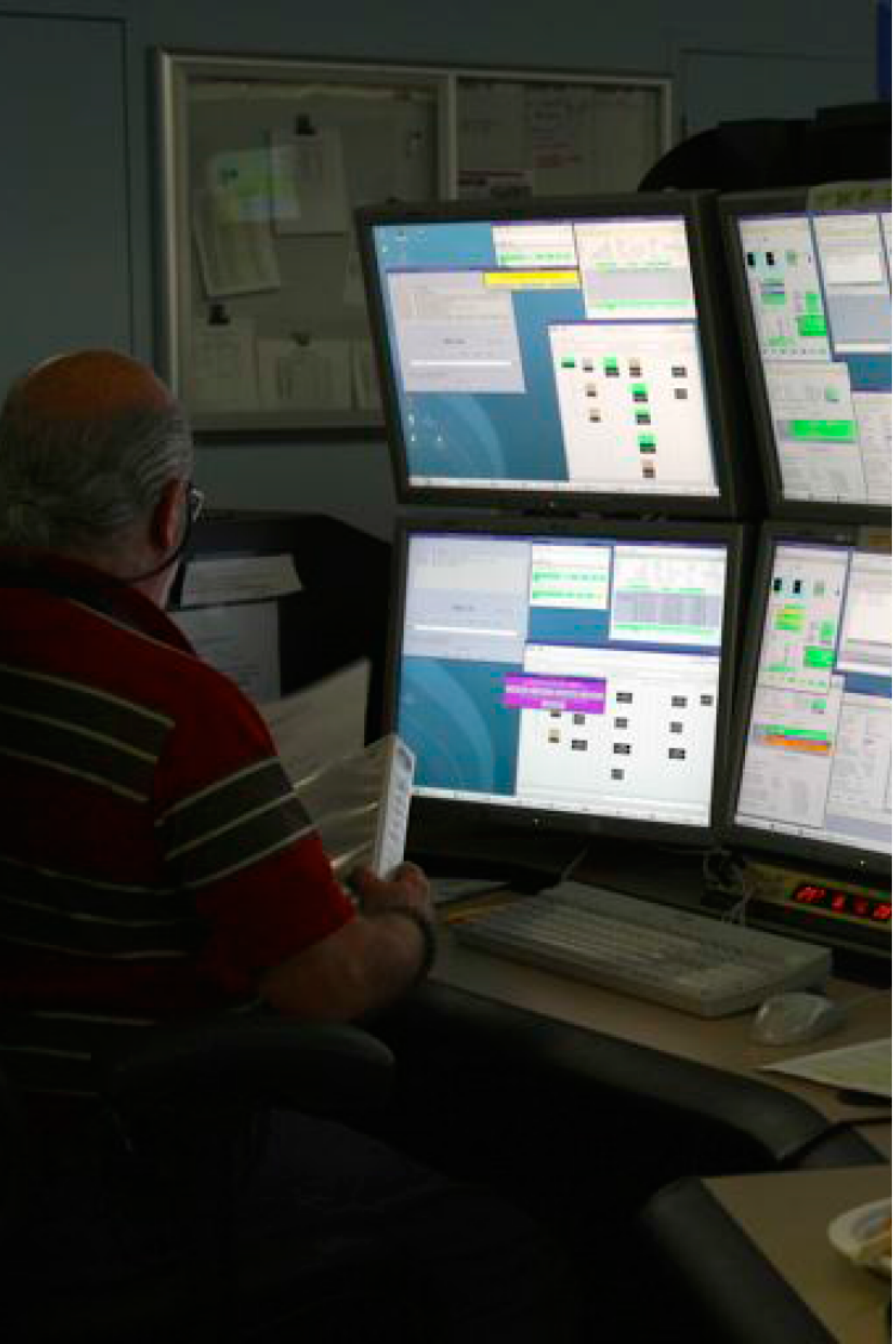
Required simultaneous secondary tasks

Highly trained operators

Complex systems need complex supervisors





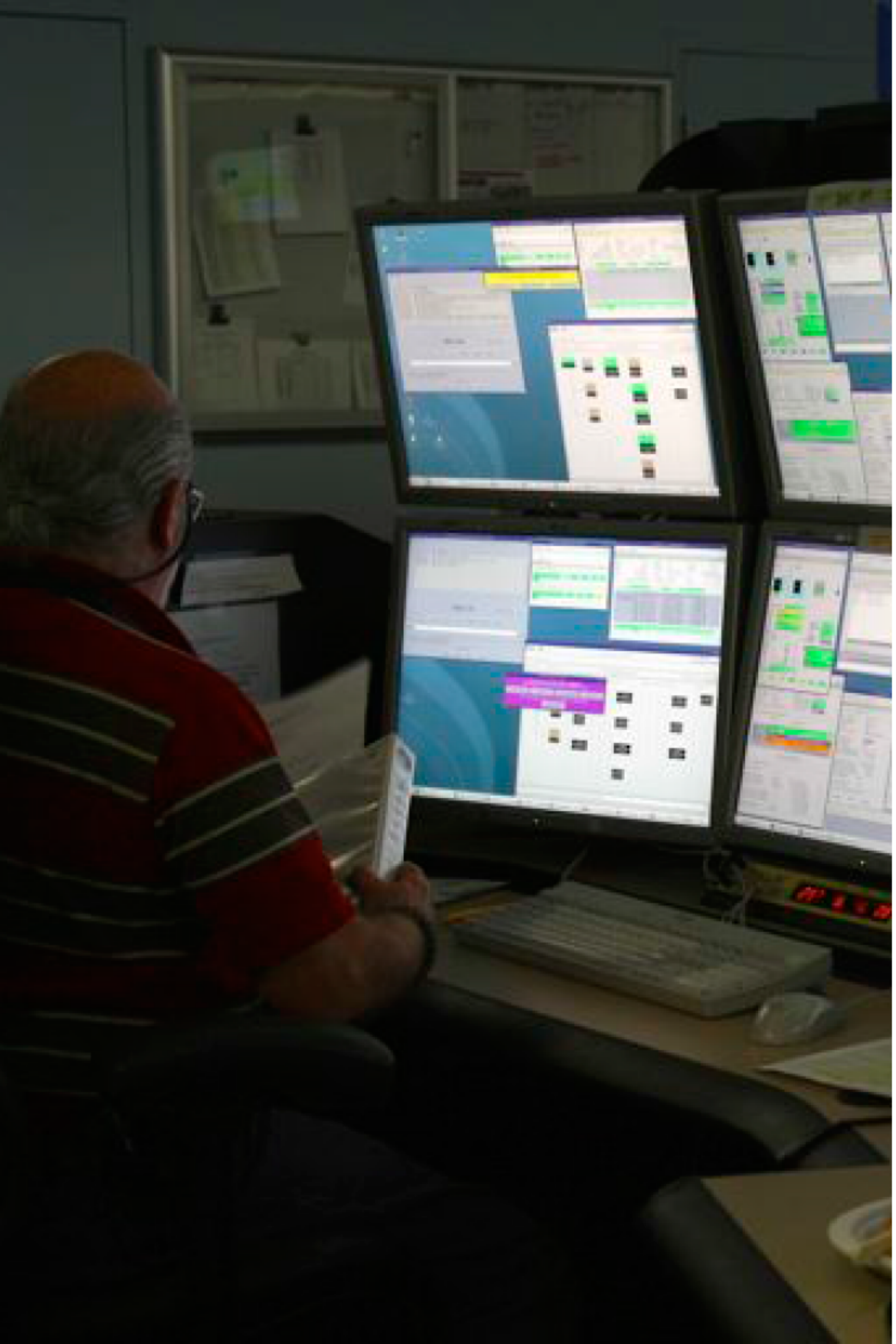


In the head

Forming and maintaining a mental model of the system

In the world

System response to dynamic activity and operator input



In the head

Forming and maintaining a mental model of the system

In the world

System response to dynamic activity and operator input

If this were a cache

We would call this *coherence*

(but instead we can call it alignment)

Maintaining alignment in a partially-automated world

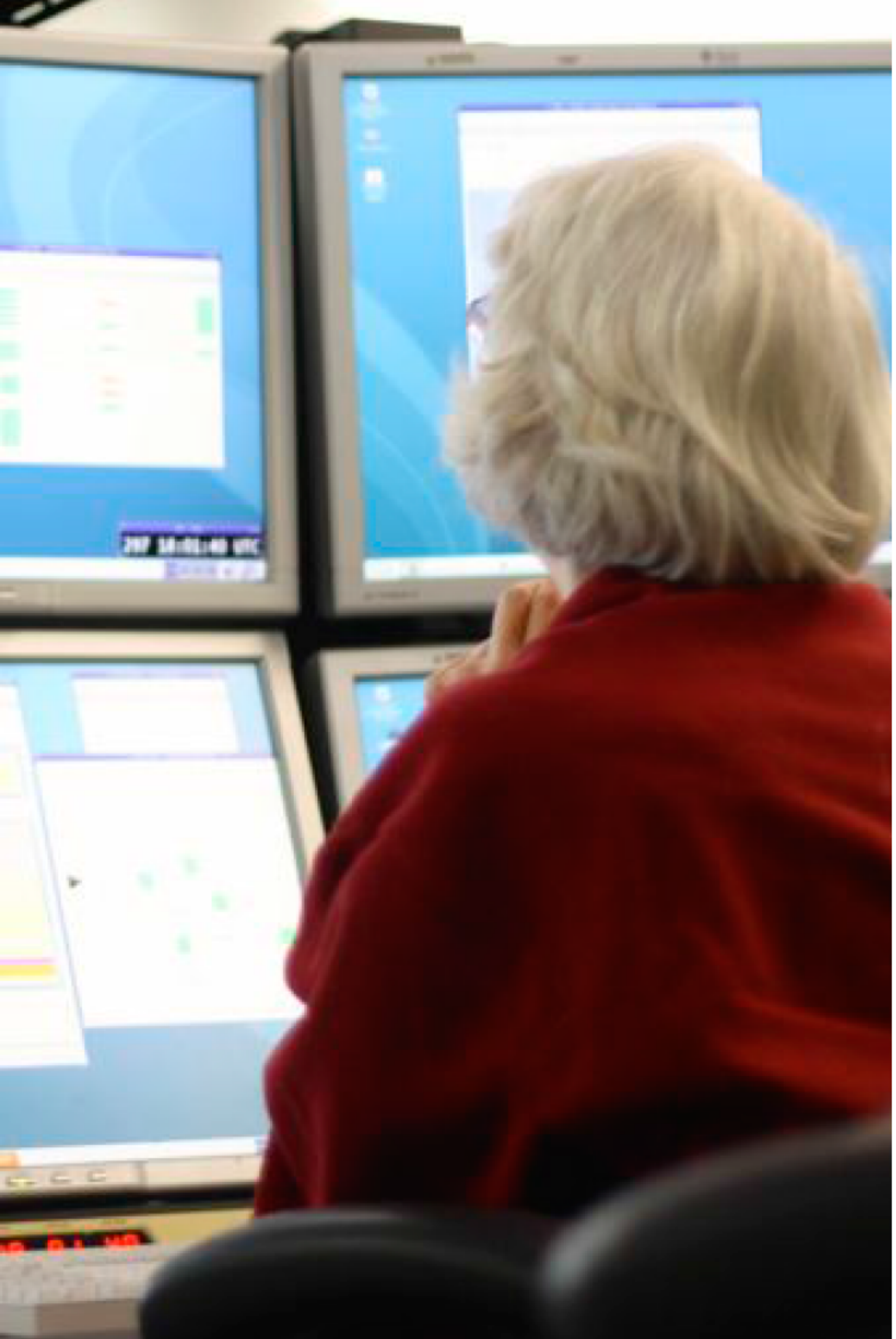
Situation Awareness

L1 Perception
of elements in current situation

L2 Comprehension
of the perceived data

L3 Projection
of future states

(Endsley, 1988)



Task Action Sequence

Execution

1 Set goals

2 Intend to act

3 Specify actions

4 Execute actions

Evaluation

5 Perceive system state

6 Interpret

7 Evaluate the outcome

(Norman, 1988)

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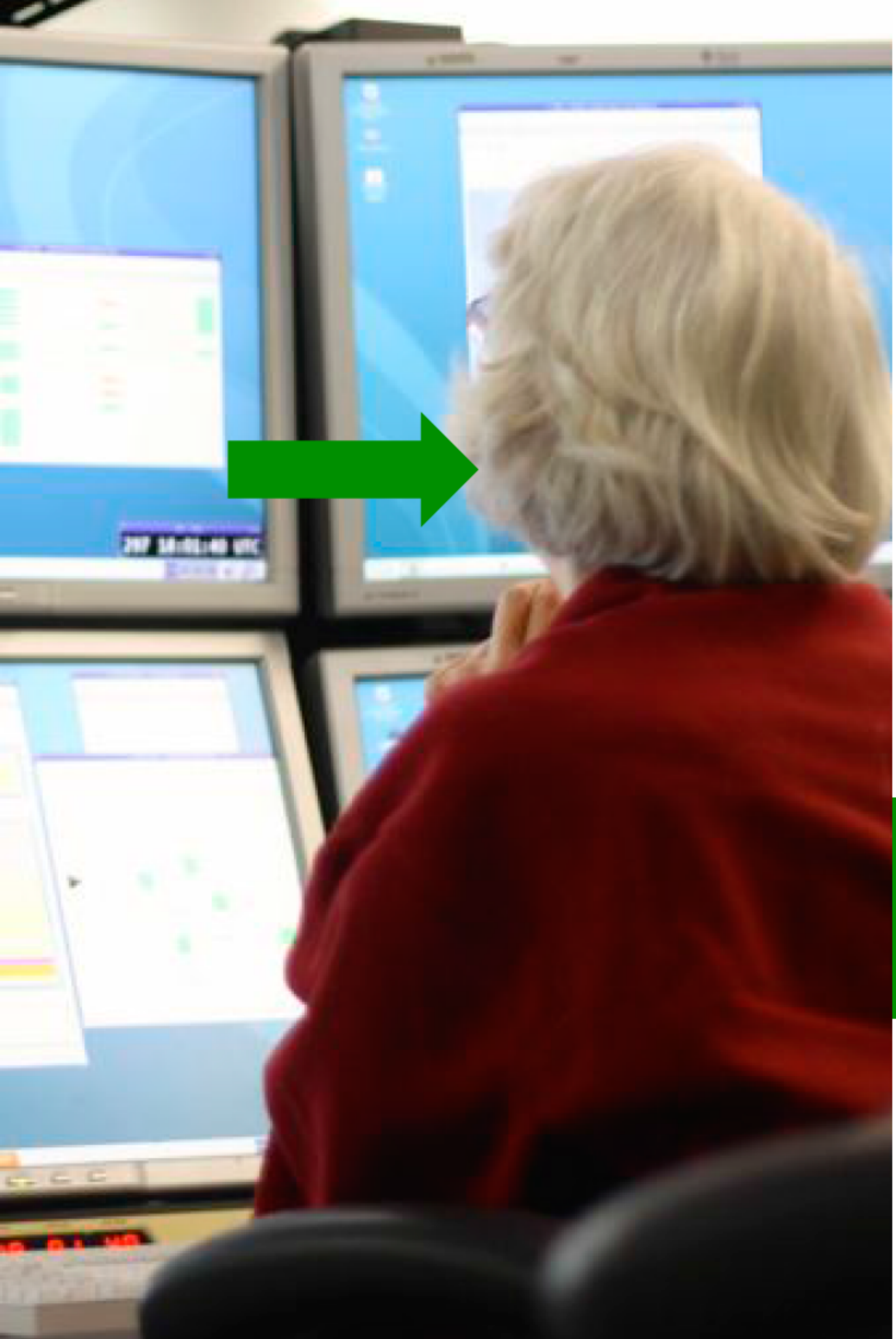

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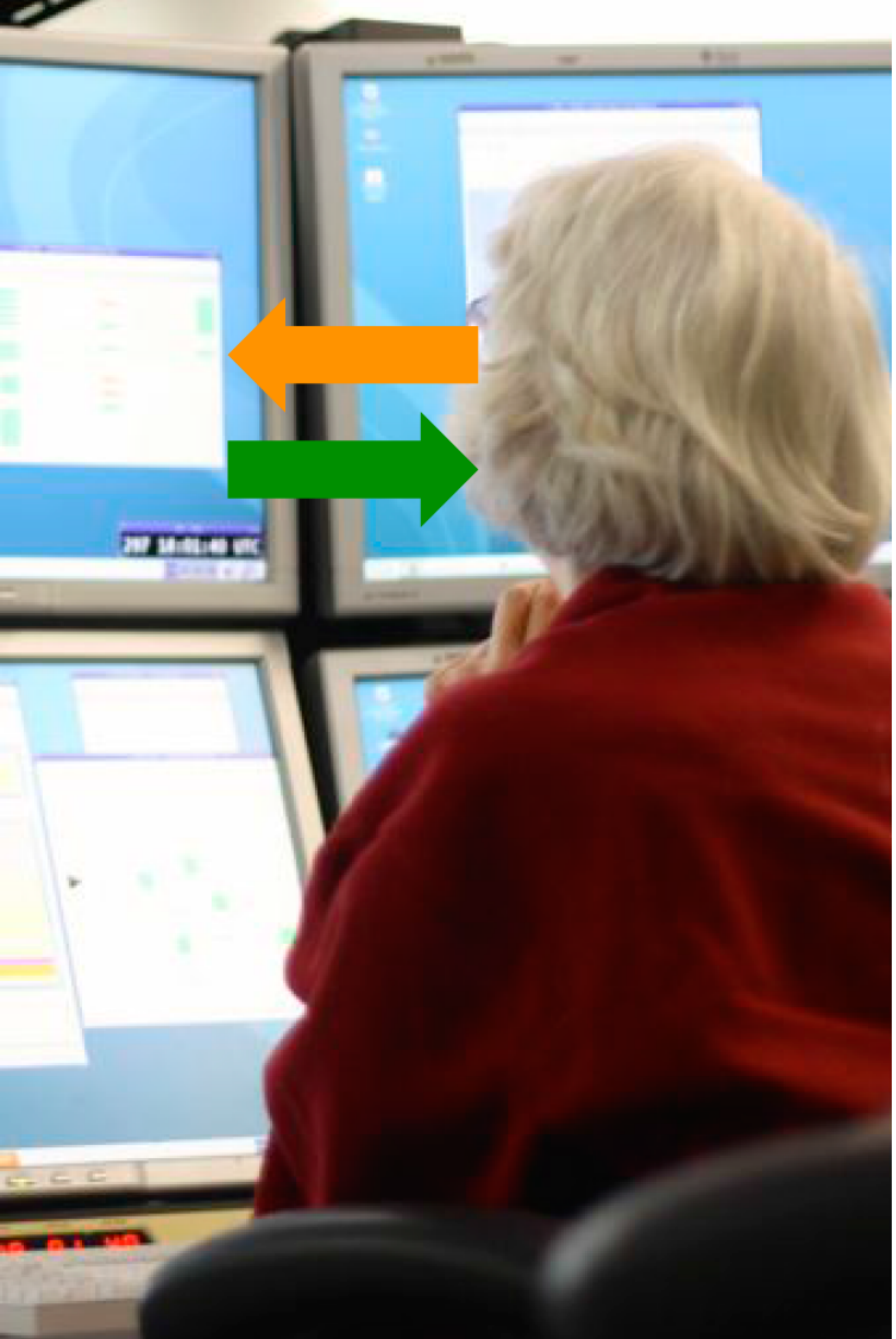

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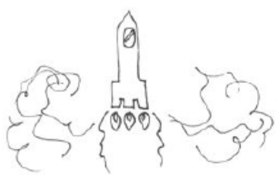


The Deep Space Network What it is, how operators work it, and what we learn

The Postage Stamp Intervention design, implementation, and reception

Implications Automation, simulation, design analogy, and situation awareness advancements

Operating the Deep Space Network

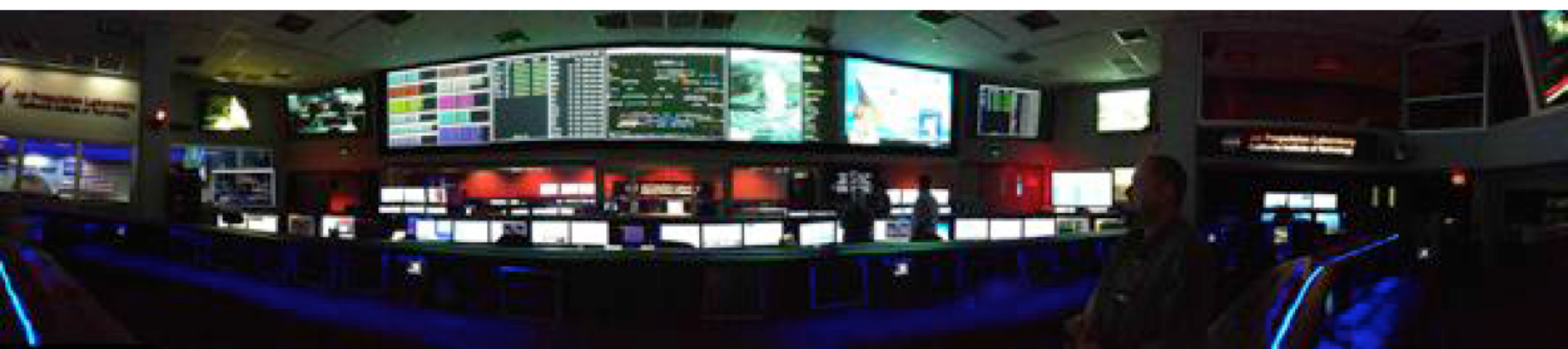
1 **Allocate resources**
Set up and ensure proper working order of equipment for support activities

2 **Operate and troubleshoot**
Ensure supports are handled according to project instructions; prevent and respond to anomalies

3 **Coordinate activities**
Work with maintenance and test crews

4 **Report and verify**
Ensure and assist discrepancy reporting

5 **Ensure safety**
Be up to date on training and aware of surroundings



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Be up to date on training and aware of surroundings

Prepare
Verify necessary support documents and equipment

Step 1

Pre-cal
Configure, calibrate equipment

Step 2

In-Track
Provide necessary support

Step 3

Post-cal
Cool down and stow equipment

Step 4

Report
Document discrepancies

Step 5

Prepare
Verify necessary support documents and equipment

Step 1

Pre-cal
Configure, calibrate equipment

Step 2

In-Track
Provide necessary support

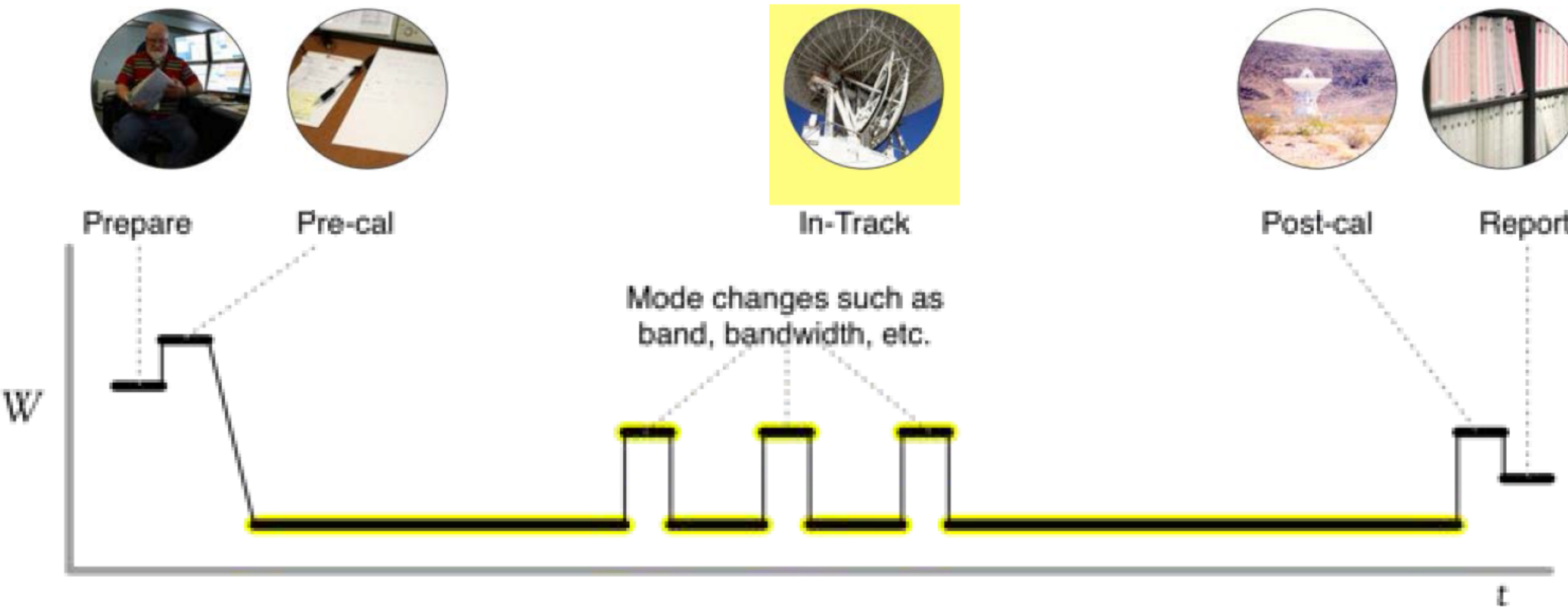
Step 3

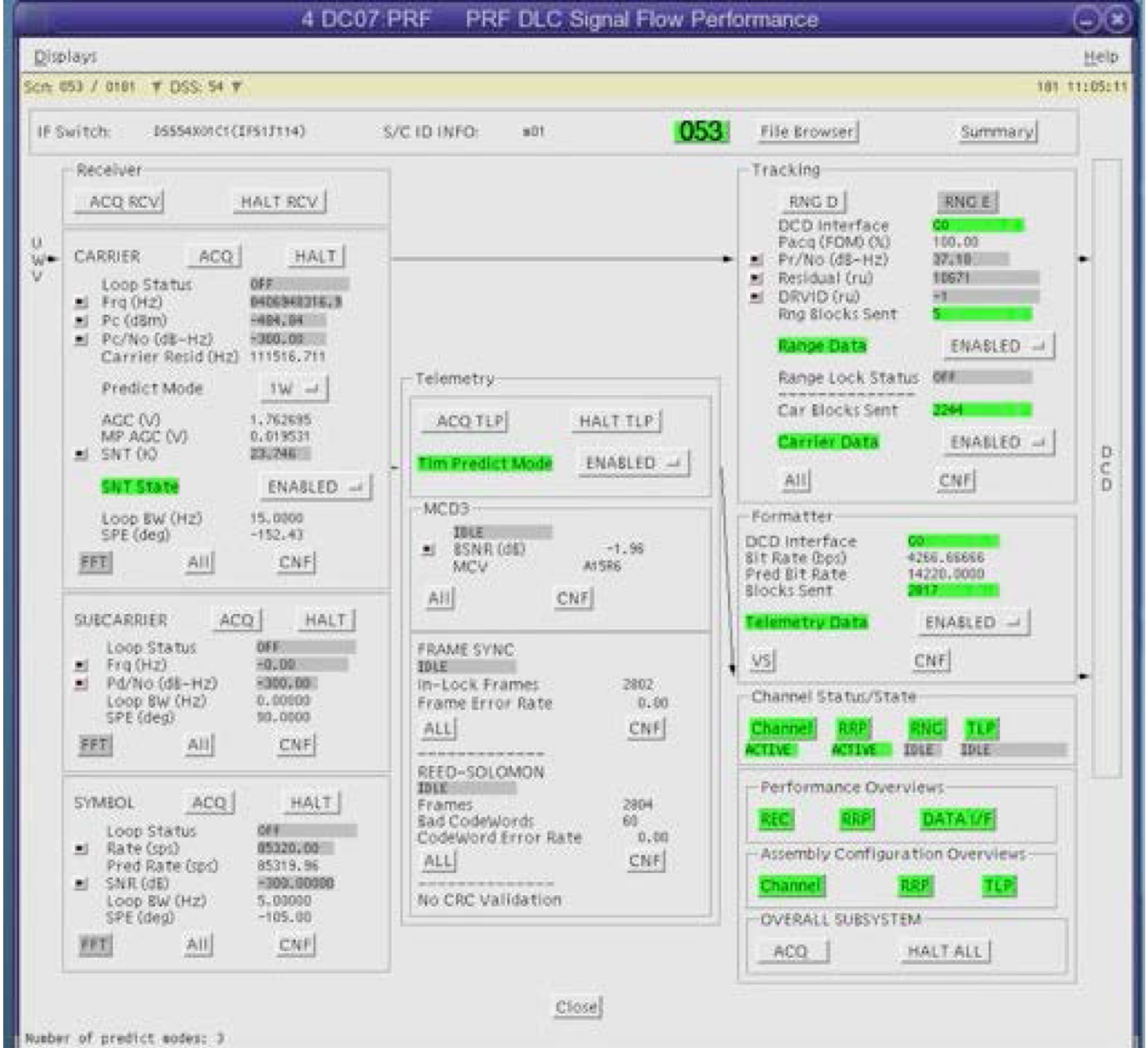
Post-cal
Cool down and stow equipment

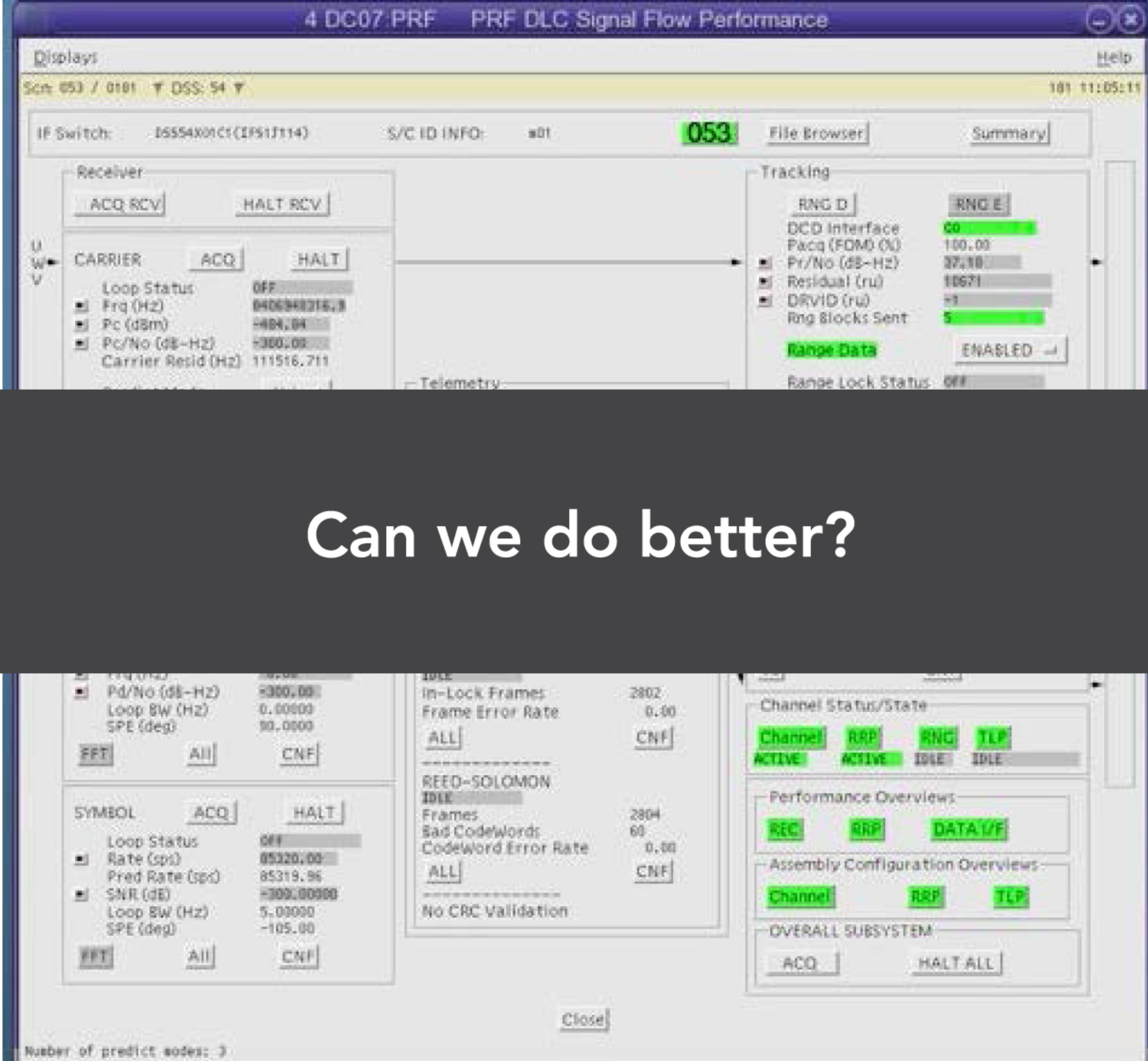
Step 4

Report
Document discrepancies

Step 5


Prepare
Pre-cal
In-Track
Post-cal
Report
Mode changes such as
band, bandwidth, etc.
W
t


4 DC07 PRF PRF DLC Signal Flow Performance
Displays
Help
IF Switch:
S/C ID INFO:
053
File Browser
Summary
Receiver
ACQ RCV
HALT RCV
CARRIER
ACQ
HALT
Loop Status
Frq (Hz)
Pc (dBm)
Pc/No (dB-Hz)
Carrier Resid (Hz)
Predict Mode
AGC (V)
MP AGC (V)
SNT (K)
SNT State
ENABLED
Loop BW (Hz)
SPE (deg)
FFT
All
CNF
SUBCARRIER
Pd/No (dB-Hz)
SYMBOL
Rate (sps)
Pred Rate (sps)
SNR (dB)
Telemetry
ACQ TLP
HALT TLP
Tlm Predict Mode
MCD3
IDLE
BSNR (dB)
MCV
FRAME SYNC
In-Lock Frames
Frame Error Rate
ALL
REED-SOLOMON
Frames
Bad Codewords
Codeword Error Rate
No CRC Validation
Tracking
RNG D
RNG E
DCD Interface
Pacq (FOM) (%)
Pr/No (dB-Hz)
Residual (ru)
DRVID (ru)
Rng Blocks Sent
Range Data
Range Lock Status
Car Blocks Sent
Carrier Data
Formatter
Bit Rate (bps)
Pred Bit Rate
Blocks Sent
Telemetry Data
VS
Channel Status/State
Channel
RRP
RNG
TLP
ACTIVE
Performance Overviews
REC
DATA I/F
Assembly Configuration Overviews
OVERALL SUBSYSTEM
HALT ALL
DCD
Close
Number of predict modes: 3



Can we do better?

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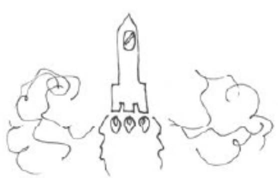

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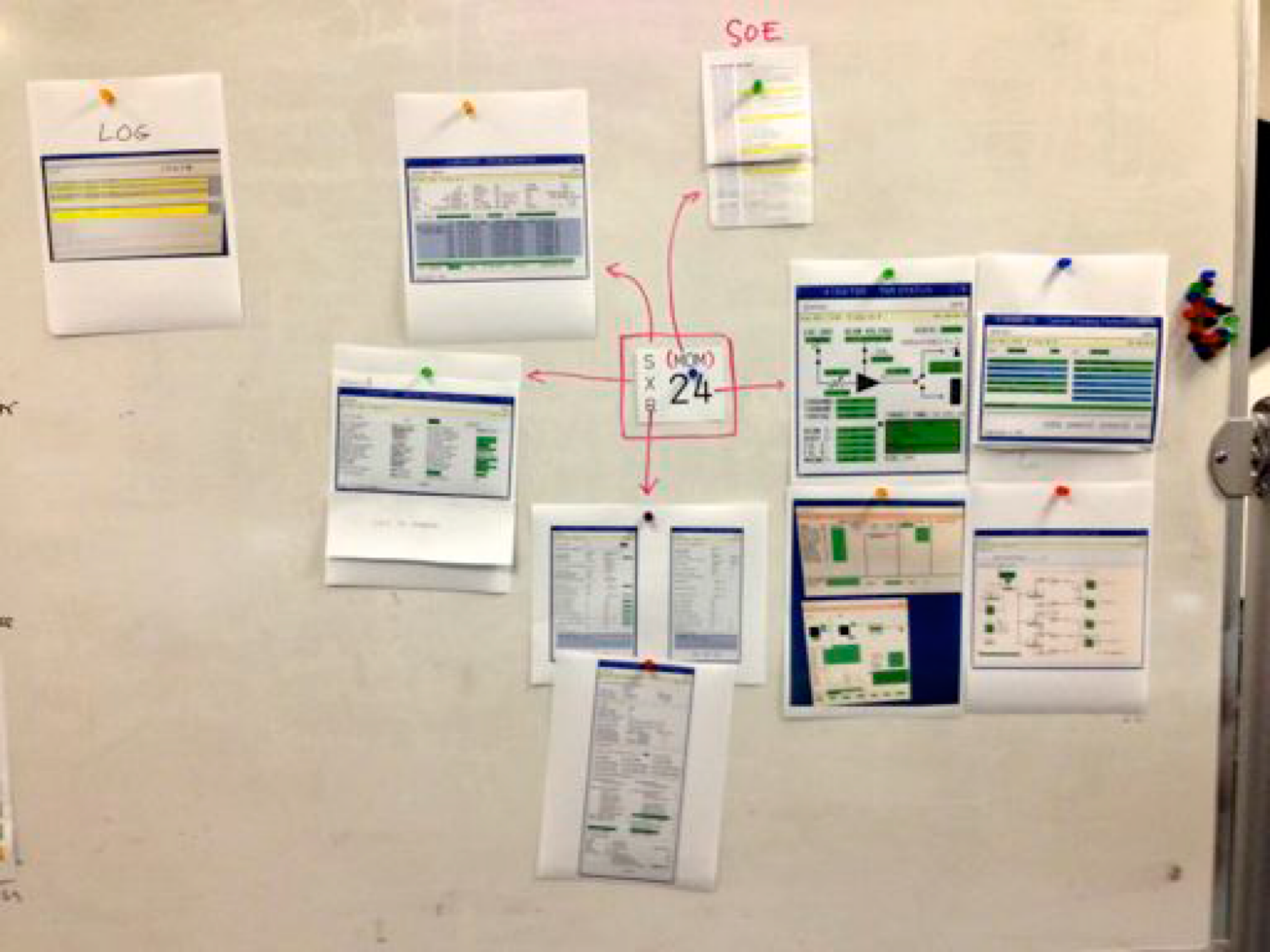
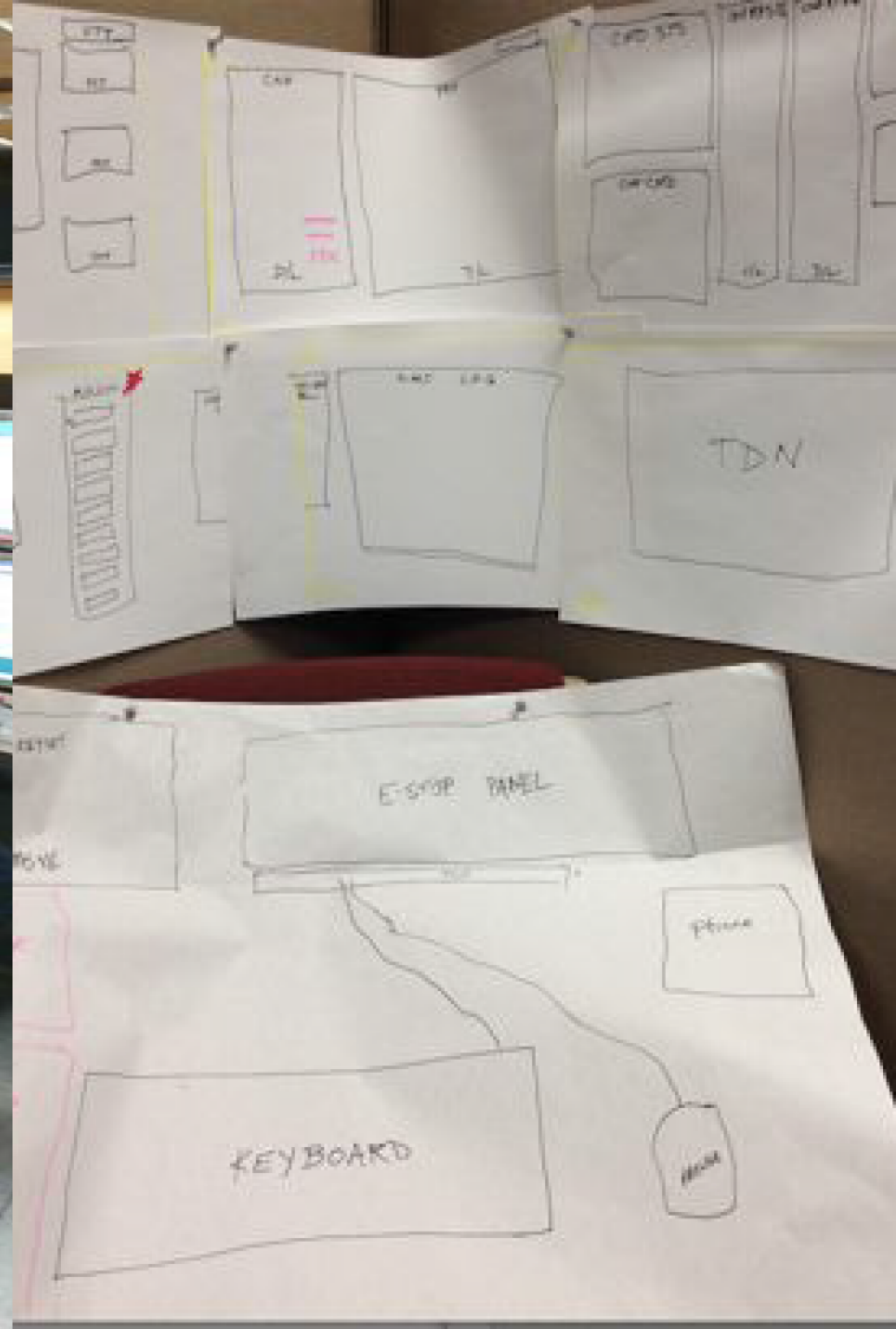
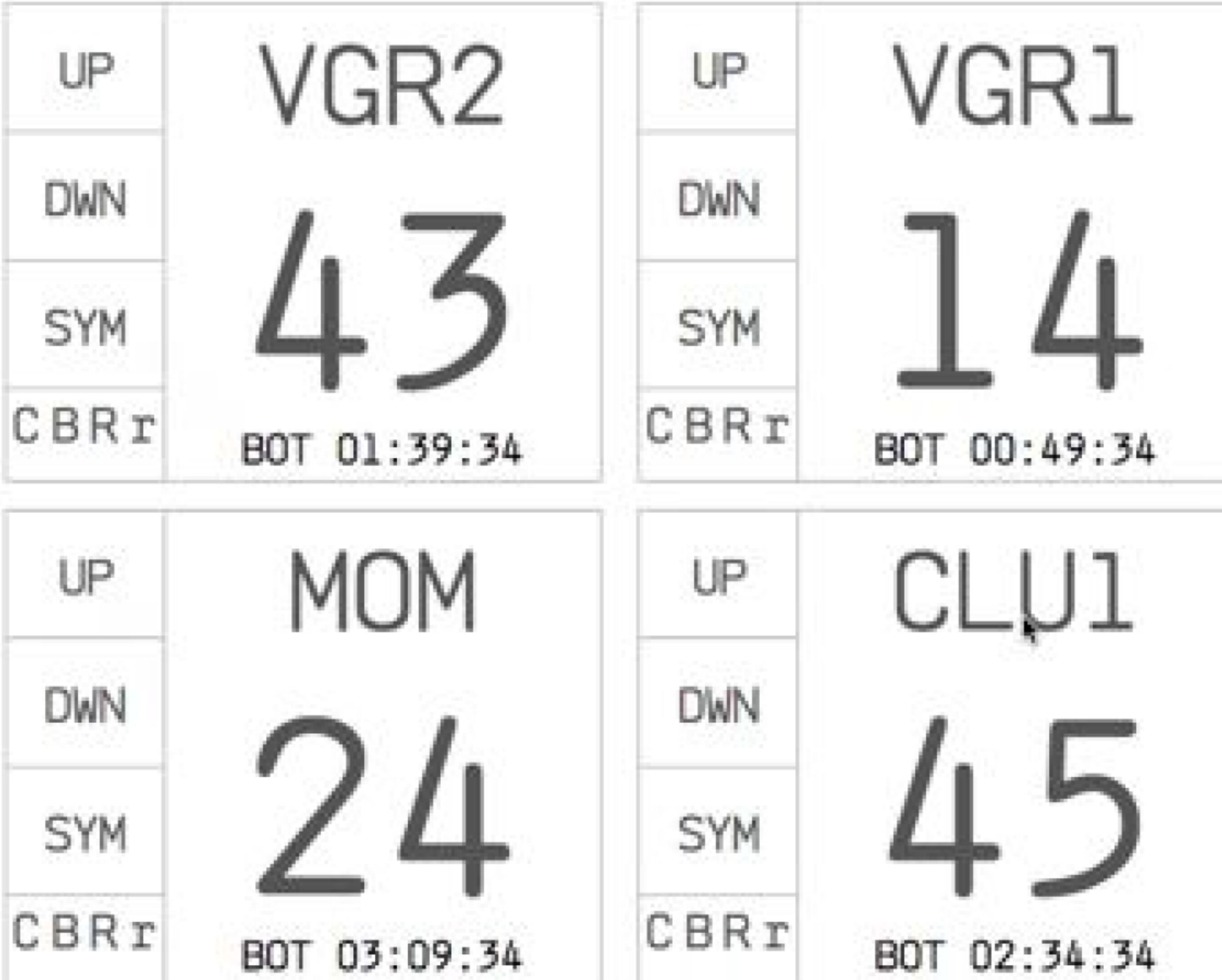

SOE
LOG
S
X
B
(MOM)
24


TDN
E-STOP PANEL
phone
KEYBOARD


25
M010
2
CJ
19.9
-125
16.9
BCRr


UP
DWN
SYM
CBRr
VGR2
43
BOT 01:39:34
UP
DWN
SYM
CBRr
VGR1
14
BOT 00:49:34
UP
DWN
SYM
CBRr
MOM
24
BOT 03:09:34
UP
DWN
SYM
CBRr
CLU1
45
BOT 02:34:34

149 07 05 26


STAMP
19.75
ON 378
OFF
-136.38
IN LOCK
OFF
STF
14
TRACKING
266.04
48.126
STAMP
2.018
ON 0
MOD2
-135.82
IN LOCK
IN LOCK
MOM
24
TRACKING
103.23
15.818

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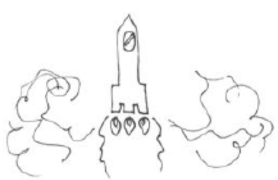

Telemetry actuals

Measured data values attached to hardware telemetry

Telemetry actuals

Measured data values attached to hardware telemetry

System expecteds

What the system expects to see, e.g. due to prediction and/or command

Telemetry actuals

Measured data values attached to hardware telemetry

System expecteds

What the system expects to see, e.g. due to prediction and/or command

Operator predicteds

What the operator expects to see given Level 3 situation awareness (projection of future states)

Actual	Expected	Predicted	
x	x		Compare to historical data and present results
x	x		Support comprehension rather than perception alone (Endsley)
x		x	“Is the antenna doing as I commanded?”
x		x	Predict what the operator will expect to see, and present results of that computation
	x	x	Condition data to remove noise
	x	x	Interpolate and/or retransmit missing data
	x	x	Flag / transform live stream to meet operator data needs
	x	x	Post-process to determine edge cases and flag errors

If you have this problem

Complex
Describing the real system is impossible or impractical

Subsetting
We are only interested in a subset of the real system

Quick iteration
We are designing something and need to iterate quickly

Evaluation
We have specific evaluation requirements

Use a simulator

Complex
Describing the real system is impossible or impractical

Subsetting
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Pitfalls in designing simulations

Pitfall 1

Data-driven simulation lacks emotion, cost, and risk

Pitfall 1

Data-driven simulation lacks emotion, cost, and risk

Create experiences, not simulations

Research the user

Find out what motivates the user towards risk-aversion

E.g., Psychosocial and sociotechnical factors

Experience prototype

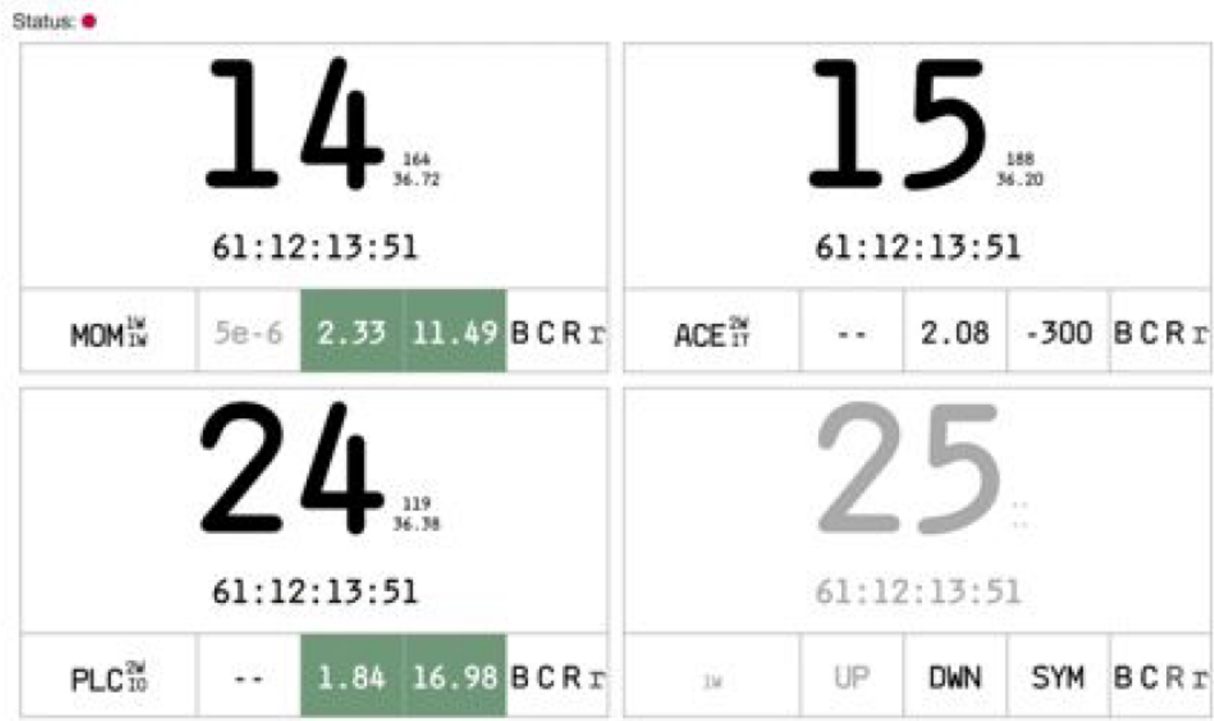
Little environmental things give the experience realism

E.g., Provide documentation, desk, environment, and distractions similar to work

Pitfall 2

Real data is difficult to obtain;

Realistic data is difficult to create



Pitfall 2

Real data is difficult to obtain; Realistic data is difficult to create

Simulate the data for data-driven simulation

Start slow

Simulate the data stream and incrementally increase the fidelity of data

E.g., Postage stamp initial prototype used simulated data stream

Test the concept, not the design

Identify the concept under test, and tailor the design to the data

E.g., Concept is summary display for increased SA; design is the physical layout of the display

Use people where you lack data

Wizard-of-Oz techniques that apply experts to the problem

E.g., Expert-as-simulator in DSN ops

Pitfall 3

Real-time simulations are slow and boring

Pitfall 3

Real-time simulations are slow and boring

Don't try to make it fun (it's not)

Use expert subjects

And make sure they are invested in the design under test

E.g., Expectant dads, not random students;
Link control operators, not designers

Test bits and pieces

Rapidly test small bite-sized chunks of the design

E.g., Testing for "glanceability" a stack of screenshots

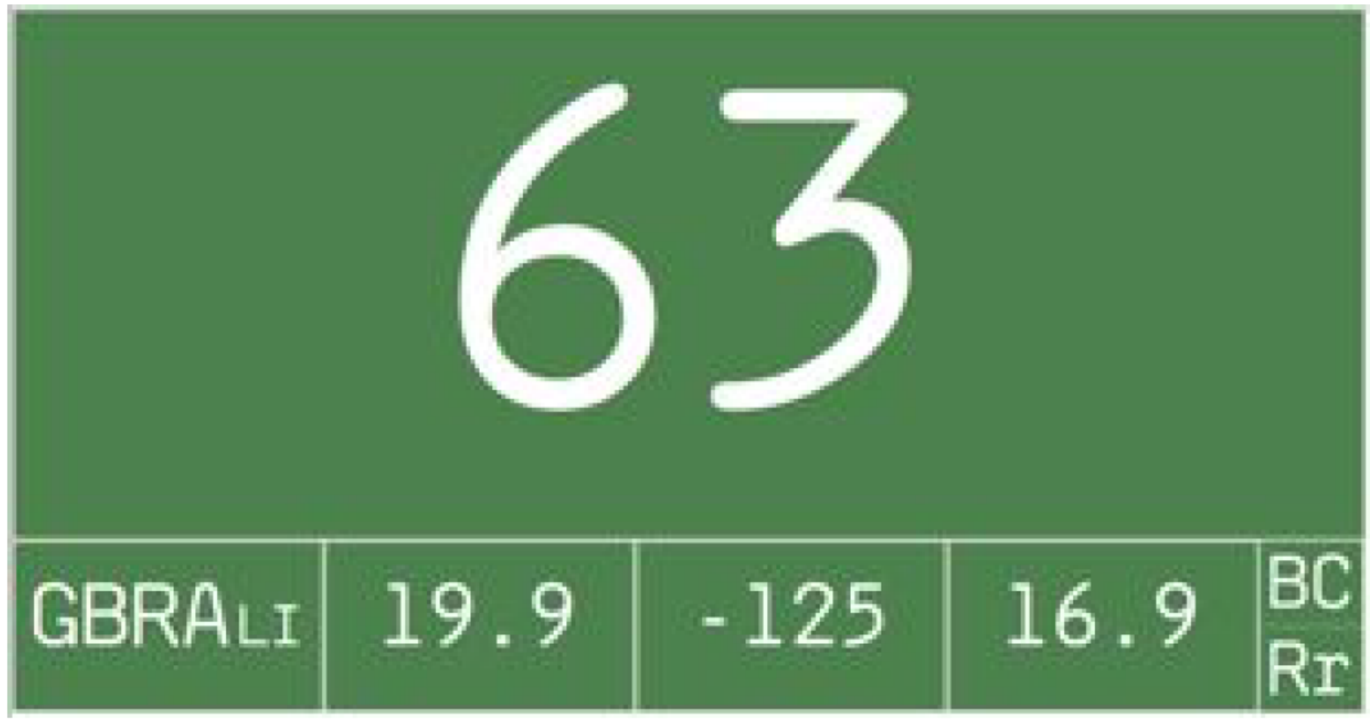
1. Provide access to time-based data such as history for operators to correlate current behavior with past behavior, or predicted behavior to current behavior
2. Make prominent relevant changes in system state, such as for when the operator looks away or tends to secondary tasks
3. Curate transition and animation for irrelevant changes to minimize distracting animation yet make salient important information
4. Provide timely data with minimal telemetry delay as determined by operator's data needs
5. Minimize latency in data transmission and in interface transitions
6. Determine and expose relationships between interrelated components and variables within the system
7. Calculate and expose differences between actuals, expecteds, and predicteds
8. Simulate first with clean, efficient, curated data
9. Grow operator attention capacity efficiently
10. Fall off from high-intensity periods gracefully

"This is so cool."

"I take back everything I was thinking about you guys. The display looks good."

Fin

Console


63
GBRALI
19.9
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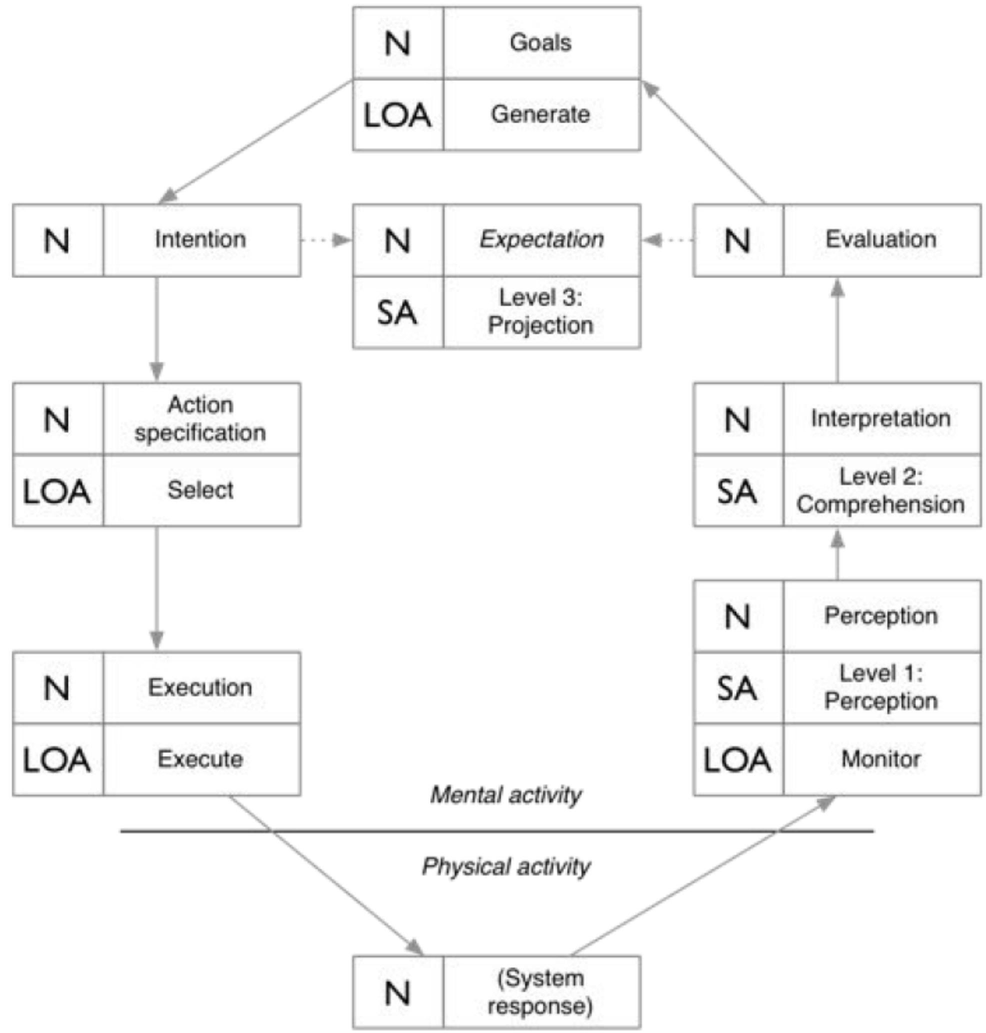
BC
Rr

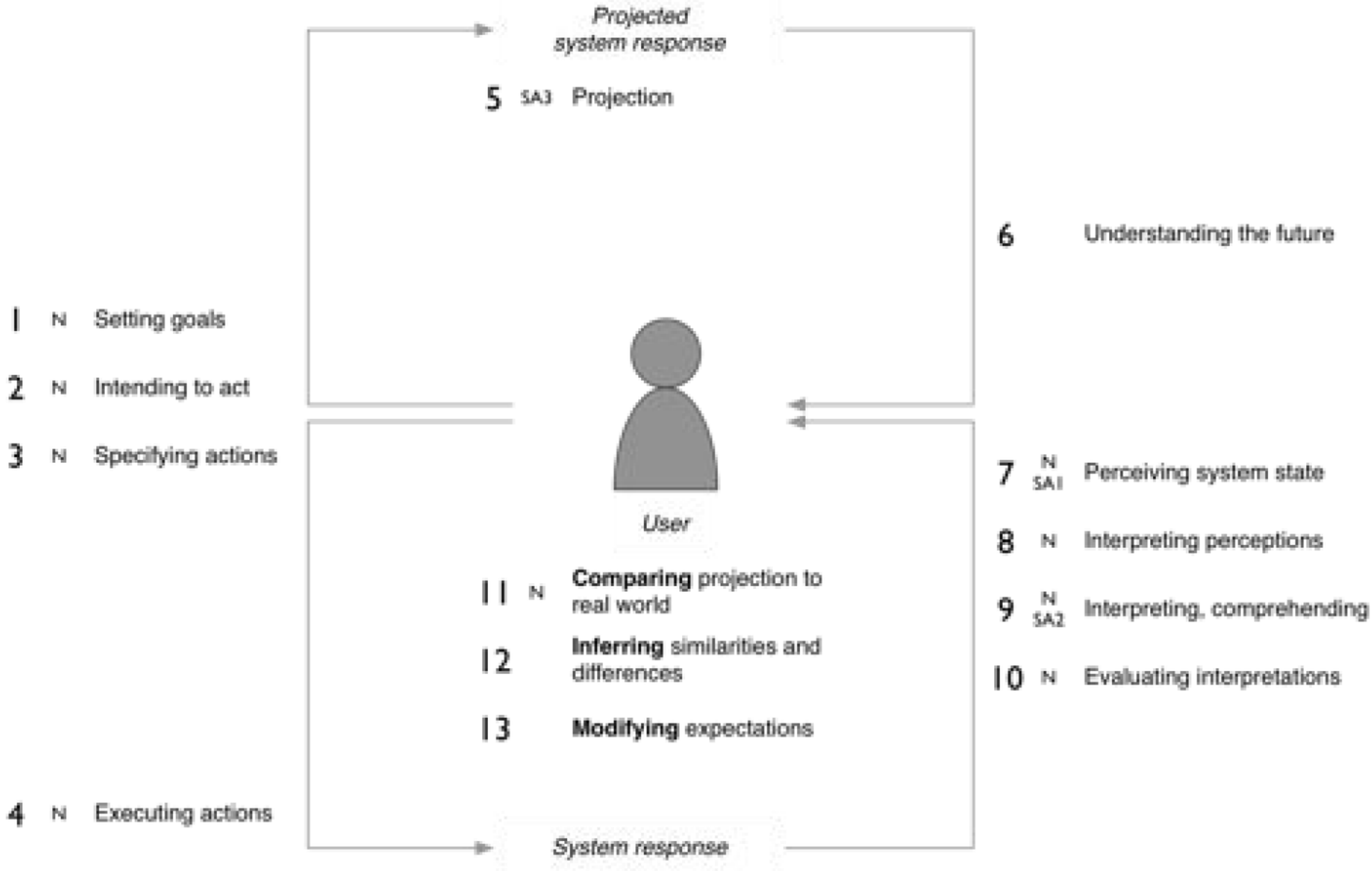
Situation Awareness

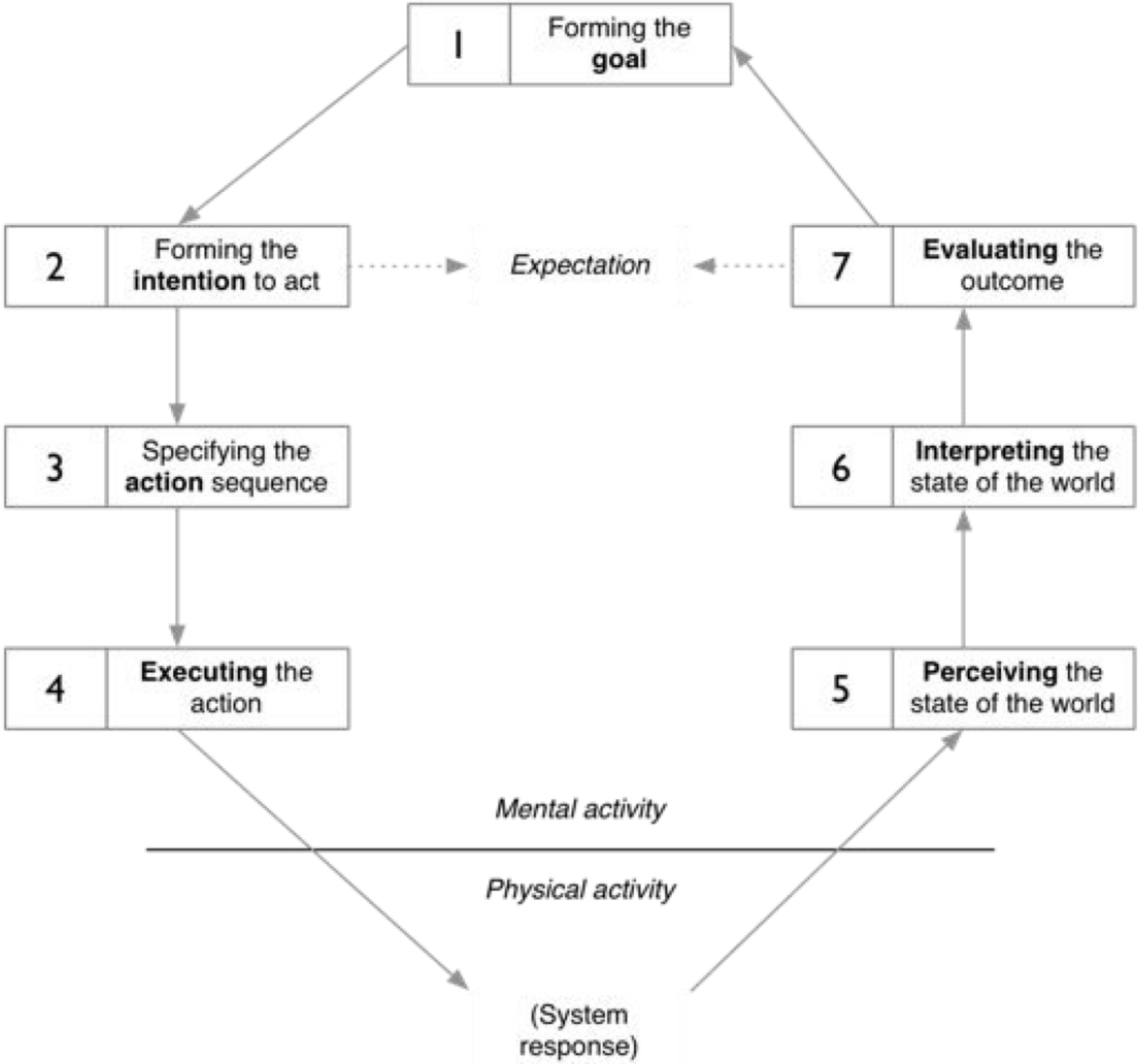
1 Perception
of elements in current situation

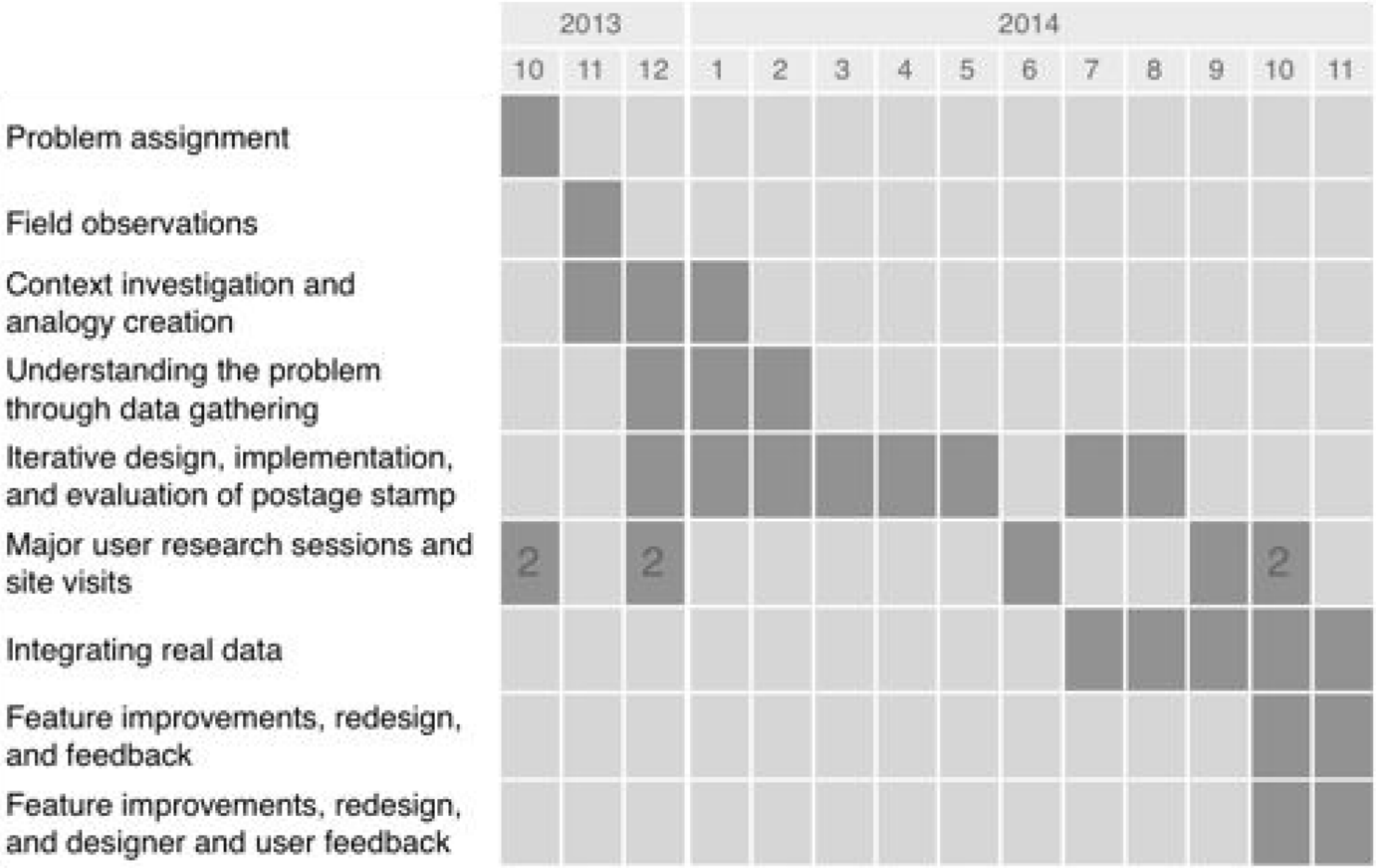
2 Comprehension
of the perceived data

3 Projection
of future states




Projected
system response
5 SA3 Projection
6 Understanding the future
1 N Setting goals
2 N Intending to act
3 N Specifying actions
User
7 N SA1 Perceiving system state
8 N Interpreting perceptions
9 N SA2 Interpreting, comprehending
10 N Evaluating interpretations
11 N **Comparing** projection to real world
12 **Inferring** similarities and differences
13 **Modifying** expectations
4 N Executing actions
System response


1
Forming the **goal**
2
Forming the **intention** to act
Expectation
7
Evaluating the outcome
3
Specifying the **action** sequence
6
Interpreting the state of the world
4
Executing the action
5
Perceiving the state of the world
Mental activity
Physical activity
(System response)


2013
2014
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10
11
Problem assignment
Field observations
Context investigation and analogy creation
Understanding the problem through data gathering
Iterative design, implementation, and evaluation of postage stamp
Major user research sessions and site visits
2
2
2
Integrating real data
Feature improvements, redesign, and feedback
Feature improvements, redesign, and designer and user feedback

Situation Awareness

1 Perception
of elements in current situation

2 Comprehension
of the perceived data

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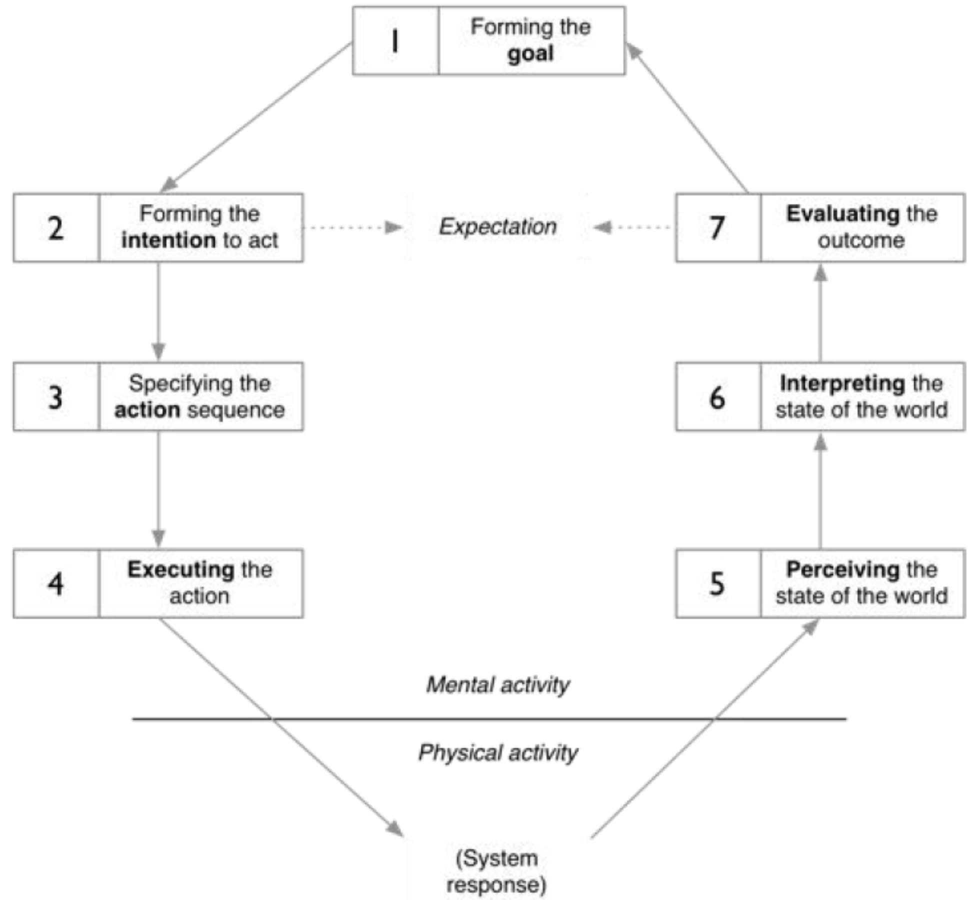
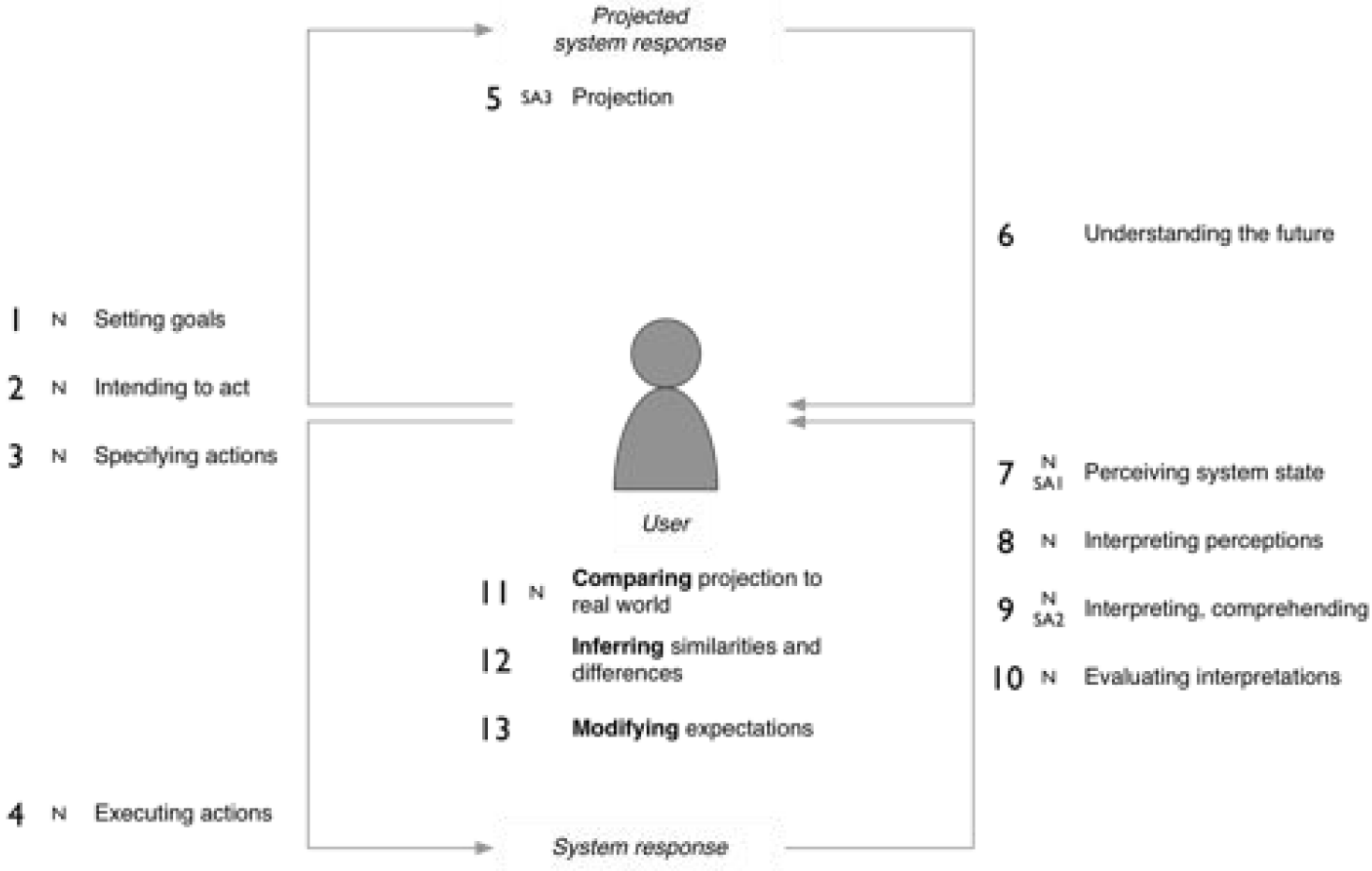
of future states

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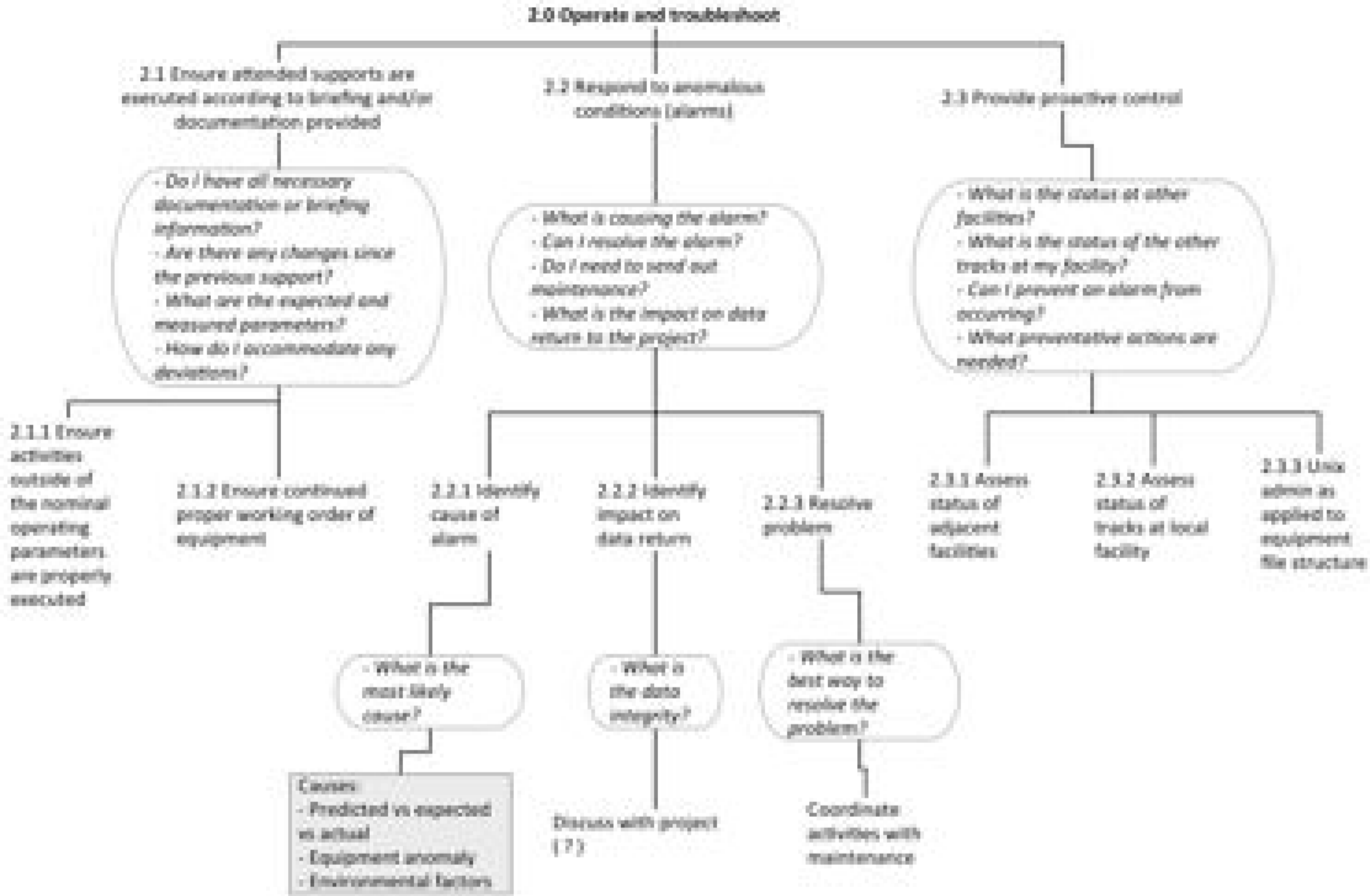
System response


2.0 Operate and troubleshoot
2.1 Ensure attended supports are executed according to briefing and/or documentation provided
2.2 Respond to anomalous conditions (alarms)
2.3 Provide proactive control
- Do I have all necessary documentation or briefing information?
- Are there any changes since the previous support?
- What are the expected and measured parameters?
- How do I accommodate any deviations?
- What is causing the alarm?
- Can I resolve the alarm?
- Do I need to send out maintenance?
- What is the impact on data return to the project?
- What is the status at other facilities?
- What is the status of the other tracks at my facility?
- Can I prevent an alarm from occurring?
- What preventative actions are needed?
2.1.1 Ensure activities outside of the nominal operating parameters are properly executed
2.1.2 Ensure continued proper working order of equipment
2.2.1 Identify cause of alarm
2.2.2 Identify impact on data return
2.2.3 Resolve problem
2.3.1 Assess status of adjacent facilities
2.3.2 Assess status of tracks at local facility
2.3.3 Unix admin as applied to equipment file structure
- What is the most likely cause?
- What is the data integrity?
- What is the best way to resolve the problem?
Causes:
- Predicted vs expected vs actual
- Equipment anomaly
- Environmental factors
Discuss with project (?)
Coordinate activities with maintenance