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intelligent spacecraft
interface systems

# ELECTRONIC PROCEDURE VIEWER DESIGN FOR NEXT-GENERATION SPACECRAFT

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# Overview

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- Background
- Goals
- Methods
- Results
- Conclusions

# Fault Management Operations on Shuttle

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- Quick recovery is vital
- Caution & Warning (C&W) system designed in 1970's
- Highly interconnected systems
- Recovery procedures = paper checklists
- Crew members must time-share faults with critical tasks

McCann *et al.*, 2006

# Fault Management Operations on Next-Generation Vehicles

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- Electronic interfaces
  - Electronic procedure viewer (EPV) will replace paper checklists
  - Mode reconfigurations via electronic switches
  - Limited display real-estate

McCandless, Hilty, & McCann, 2005

# Challenges

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- Unavoidable increases:
  - Software development
  - Testing
  - Verification requirements
  - Onboard computing resources
  - Computer memory
- Additional software cost vs. improved fault management performance

# ISIS Study Goals

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- Understand operators' display usage during the fault management process
- Evaluate human performance in the multitasking environment of dynamic flight
- Understand effect of automation on fault management operations

# Operations Concepts for Time Critical Fault Management

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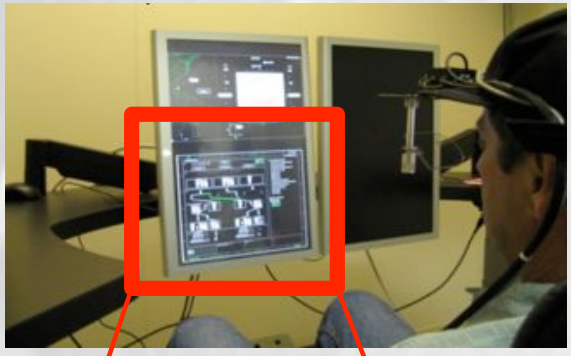
- Elsie
  - Less computationally demanding
  - Retains fault management difficulties encountered on shuttle
- Besi
  - More advanced
  - Automated root cause diagnosis
  - Failure message linked to checklist



**Elsie** **Besi**

# Method

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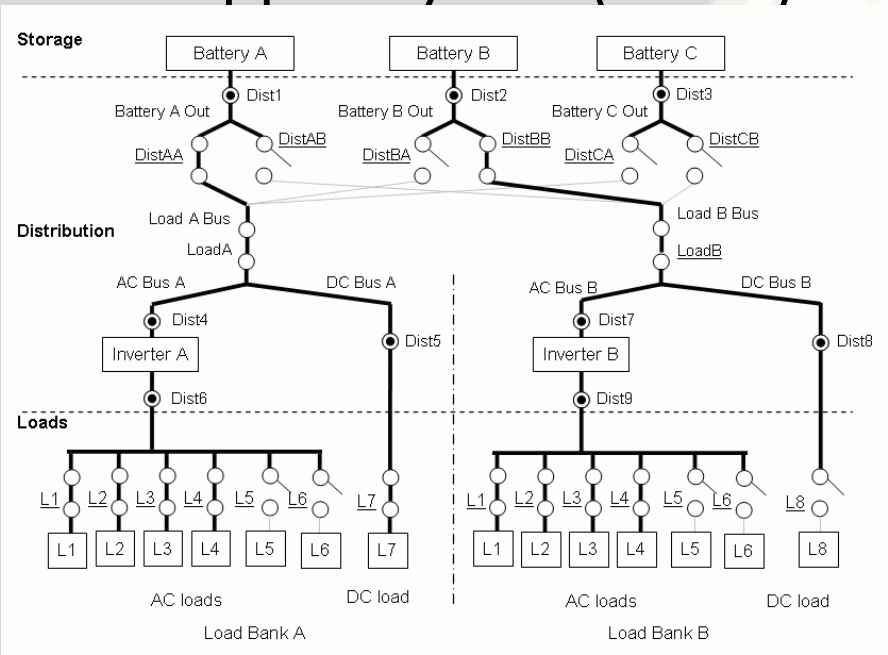
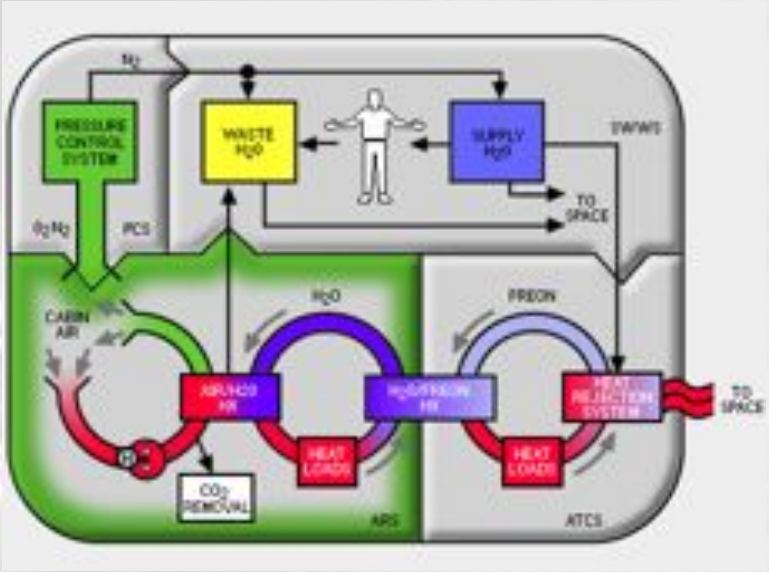
- Developed
  - Electrical power system (EPS)
  - Environmental control and life support system (ECLSS)




Electrical power system (EPS)




Environmental control and life support system (ECLSS)

# Elsie

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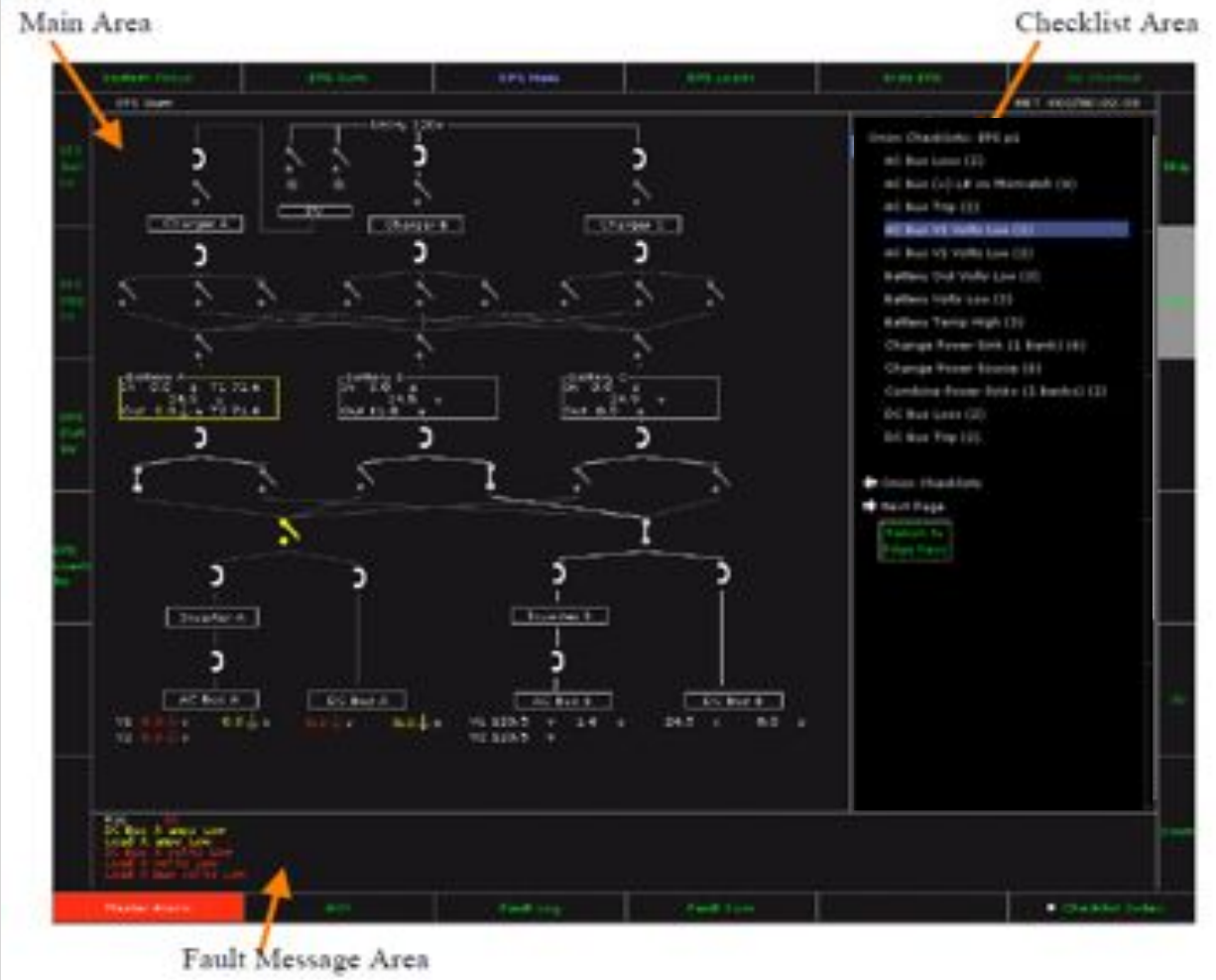


Elsie Diagnosis Phase

# Elsie

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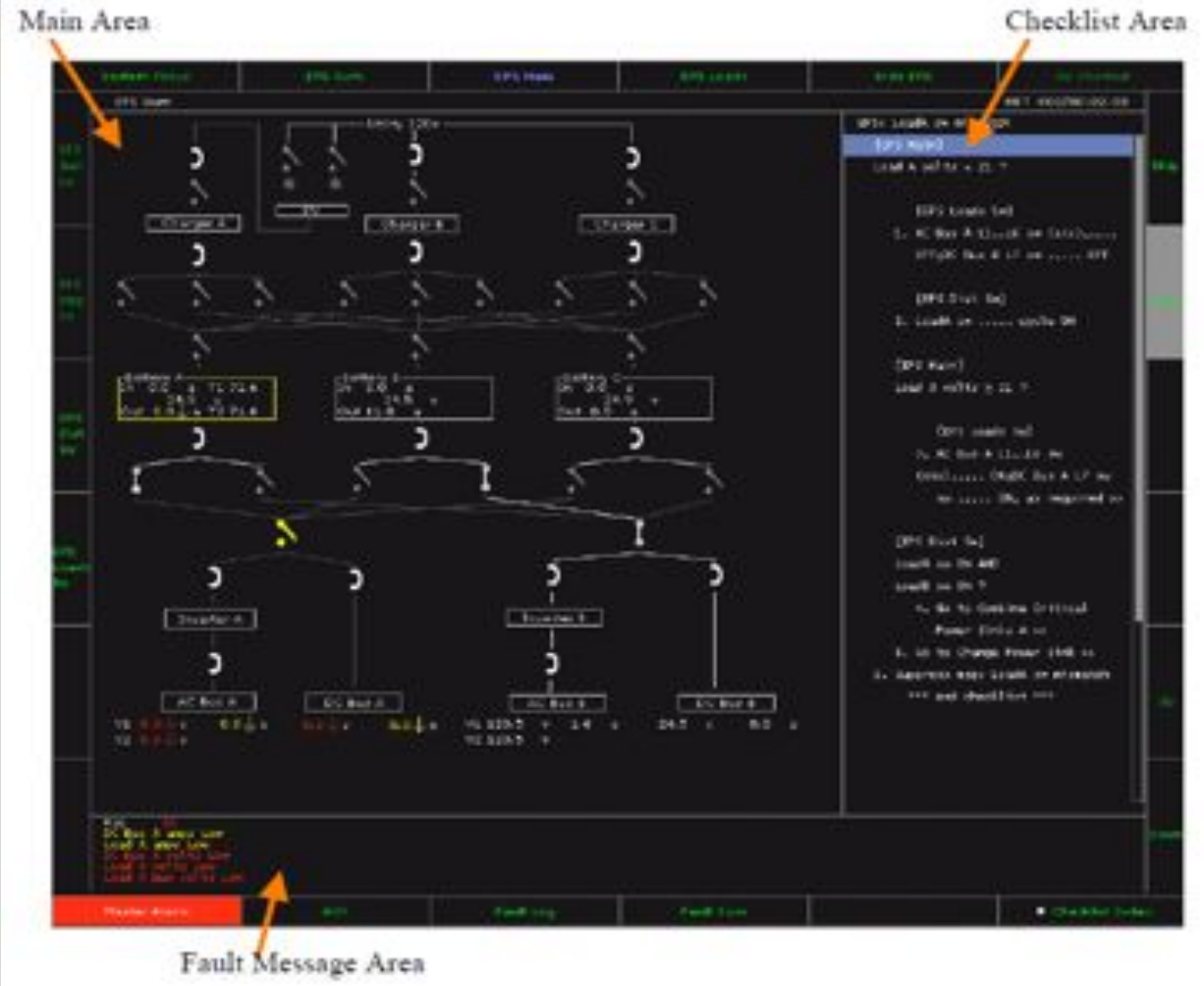


Elsie Recovery Phase

# Elsie

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# Besi

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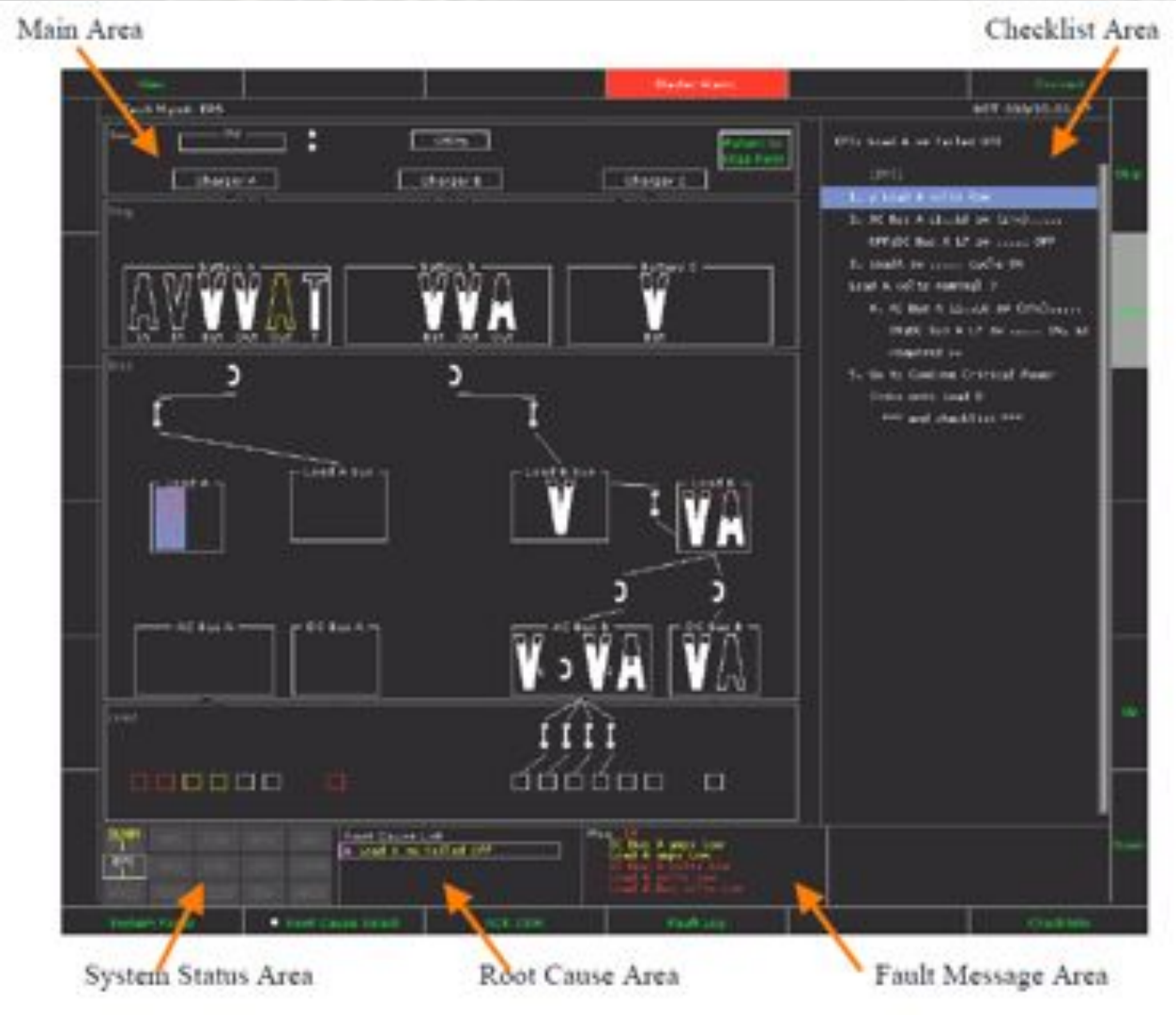

# Elsie vs. Besi

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## ELSIE

- Manually:
  - Determine root cause
  - Find recovery checklist
  - Bring up line diagram, switch panel, EPS loads, fault sum, fault log

## BESI

- Automatically:
  - Determine root cause
  - Find recovery checklist
  - Link checklist step to line diagram switch

# Method

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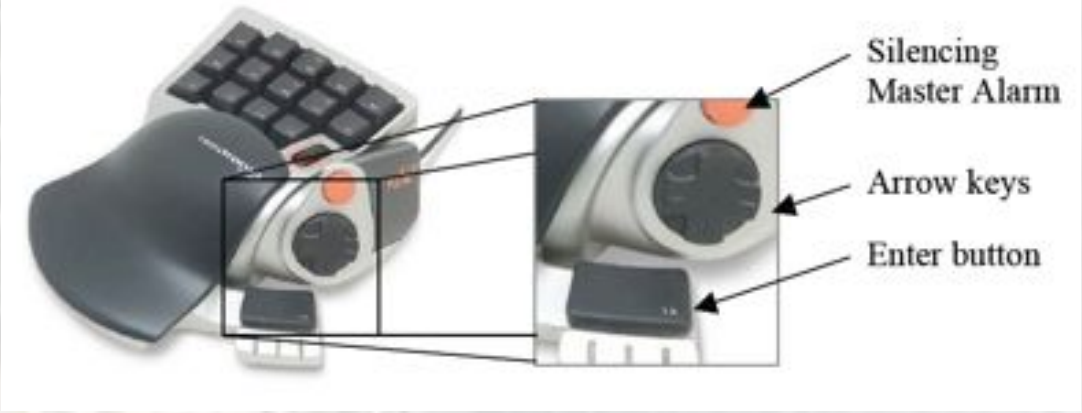
Orion CEV Simulator




Nostromo Hand Controller

- Measured operator performance during simulated Orion ascents
- One or two independent malfunctions per ascent
- Diagnose malfunction, select and complete checklist of fault isolation and recovery procedures

# Method

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- 8 operators, all instrument-rated pilots
- 12 hours of training
- Pass a final exam before data-collection
- 14 malfunction scenarios

| Scenario # | Malfunction(s) |
|---|---|
| 1 | A/L1 sw mismatch |
| 2 | B/L1 sw mismatch (false alarm) |
| 3* | 1) Load B sw mismatch (restorable)<br>2) A/L2 sw mismatch (false alarm) |
| 4* | 1) Load A sw mismatch (restorable)<br>2) B/L2 sw mismatch |
| 5 | DistAA sw mismatch (restorable) |
| 6 | DistBB sw mismatch (restorable) |
| 7 | Battery A volts low |
| 8 | Battery B volts low |
| 9 | Inverter A failure |
| 10 | Inverter B failure |
| 11* | 1) Inverter A failure<br>2) Battery A volts low |
| 12* | Same as 11 |
| 13* | 1) Battery A volts low<br>2) Battery B volts low |
| 14* | 1) Battery B volts low<br>2) Battery A volts low |

* : Multiple-malfunction scenarios

# Method

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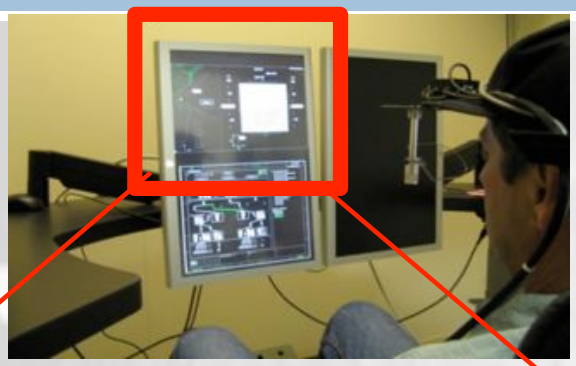
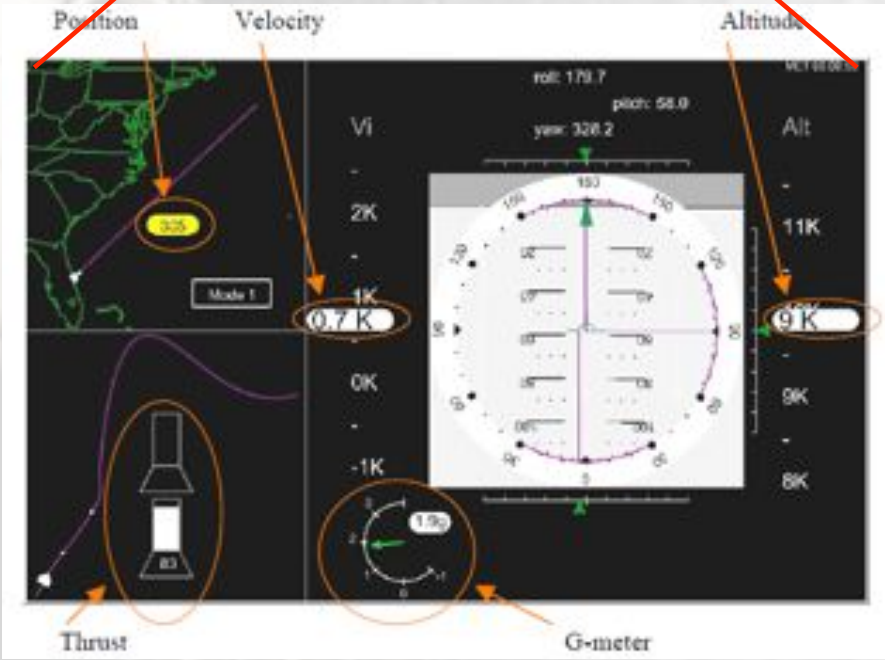
- Detect changes in display color of PFD flight parameters
- Touch PFD parameter and verbally annunciate parameter's name






Primary Flight Display (PFD)

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- Video

# Project Focus

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- Save critical DU screen space

# Electronics Procedure Viewer

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- Limited display real estate
- **Objective**
  - Determine if participants sample information above or below the current focus line
    - If the operator does not examine checklist steps before or after the current focus line, then the EPV can be shortened to only one line
  - Determine if there is a difference in information sampling behavior between Elsie and Besi

Electronics procedure viewer (EPV)

# Experimental Analysis

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- **Does the operator examine checklist steps other than the current focus line?**
  - What percentage of looks in EPV on focus line?
  - Of those not on focus line, how many looks are on each of the following steps?

Electronics procedure viewer (EPV)

# Experimental Analysis

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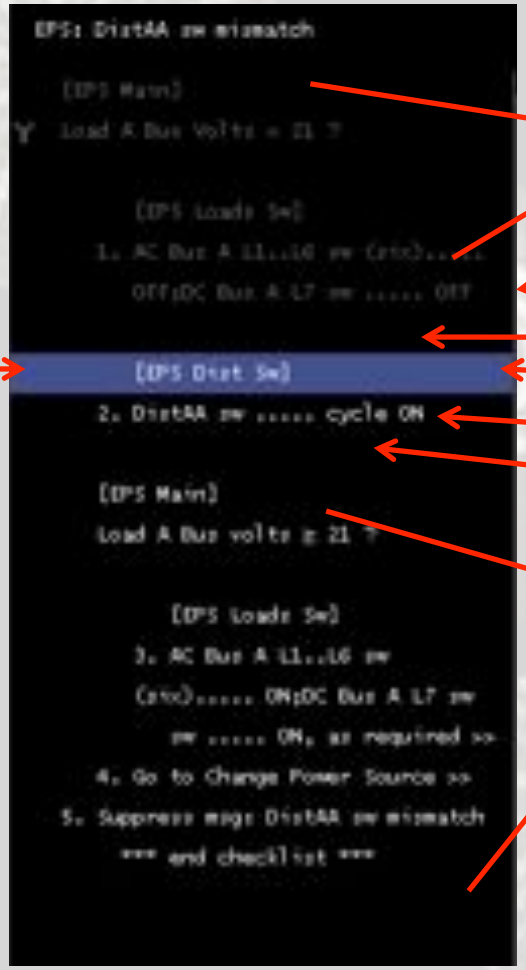


Current Focus Line

3+ Lines Above

2 Lines Above

1 Line Above

On

1 Line Below

2 Lines Below

3+ Lines Below

Electronics procedure viewer (EPV)

# Results

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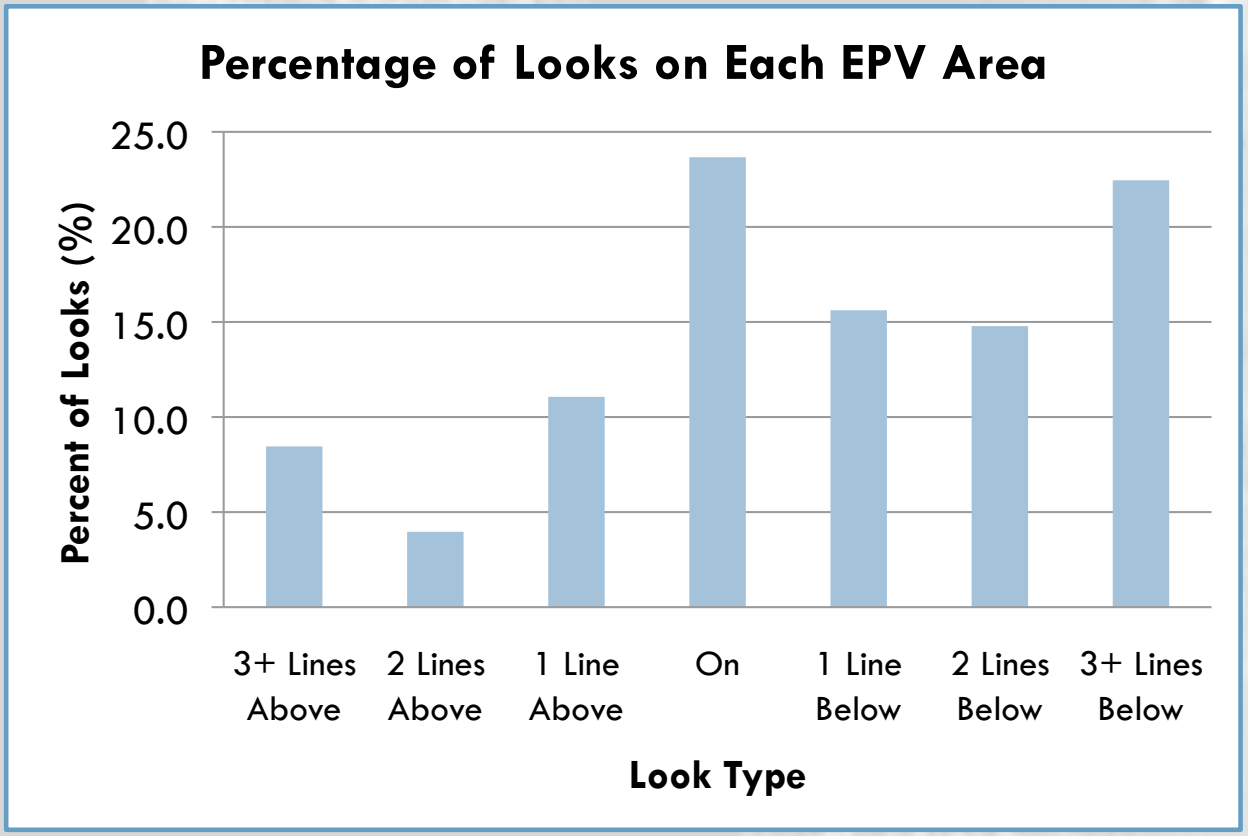

# Results

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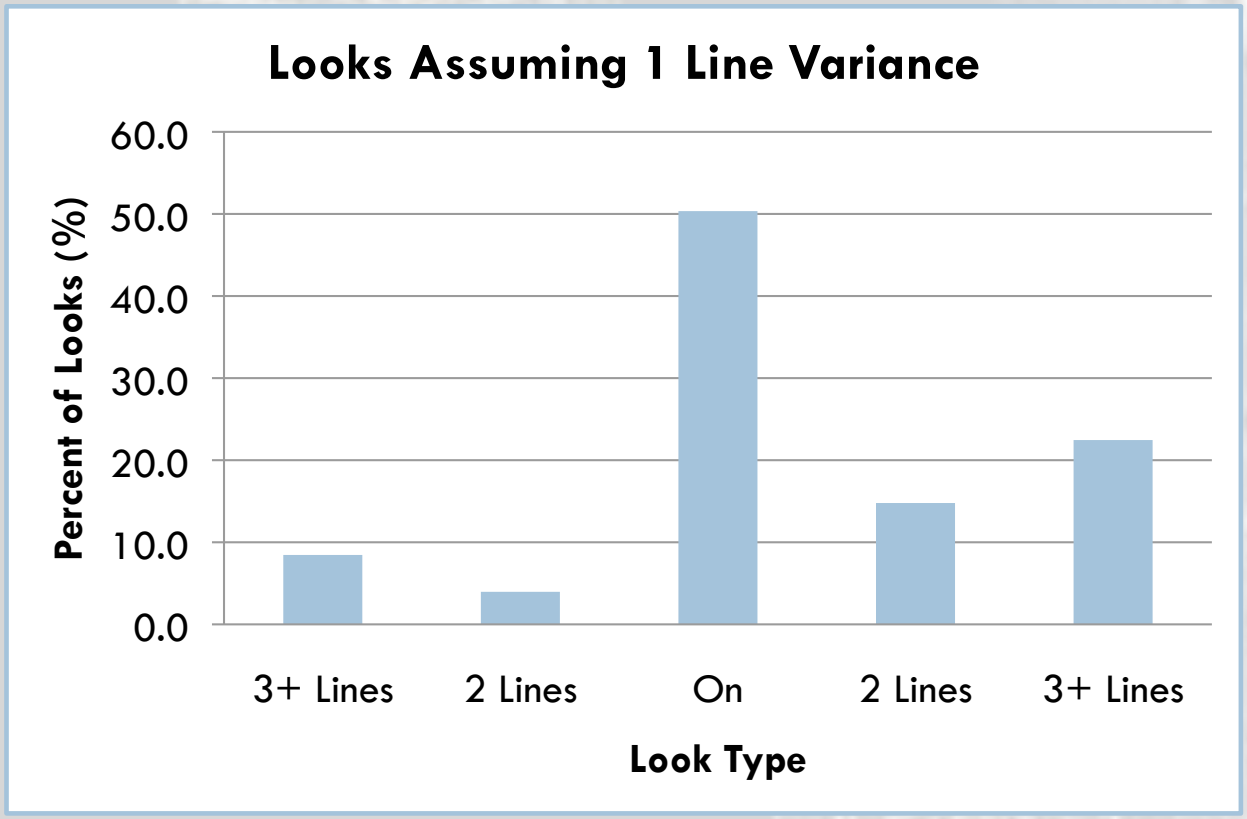

# Analysis of Long vs. Short Checklists

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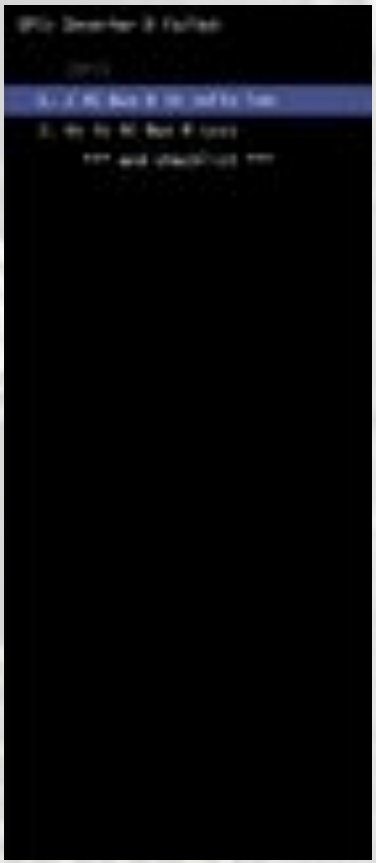

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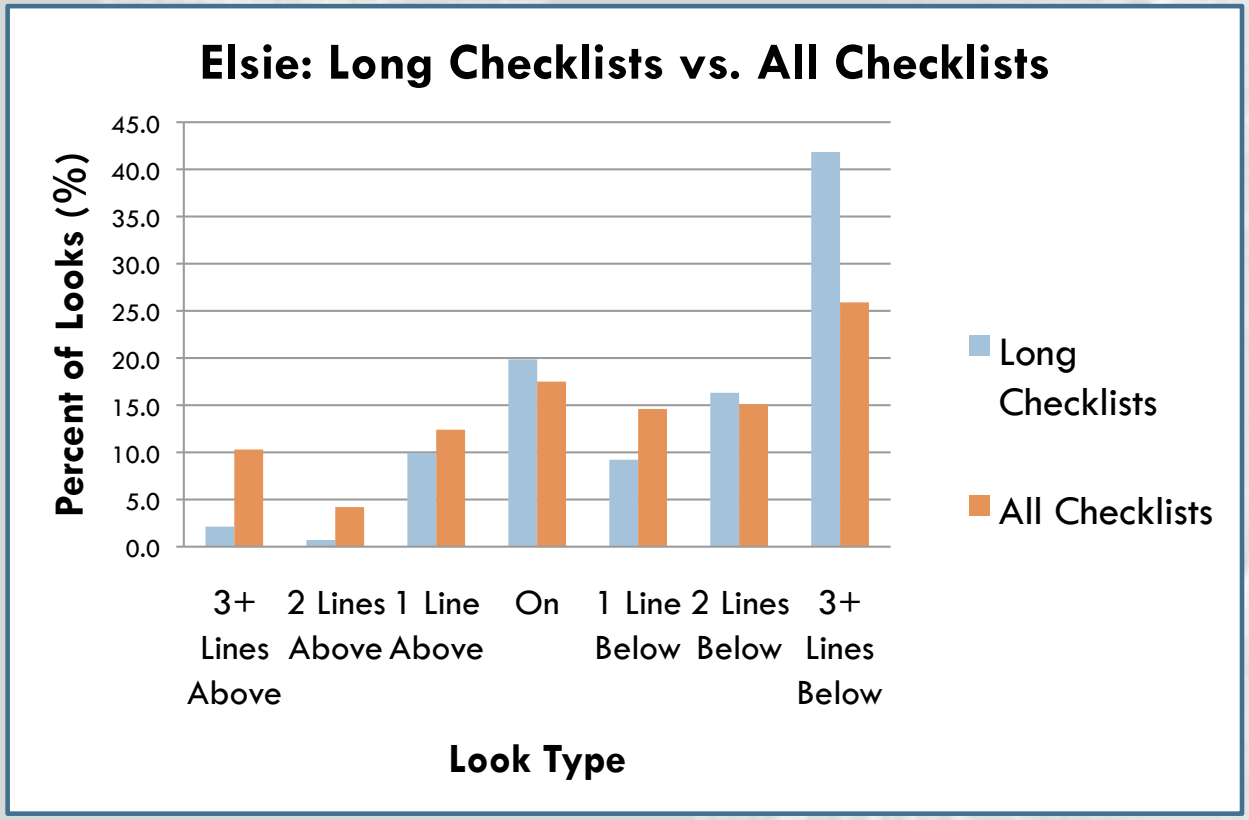

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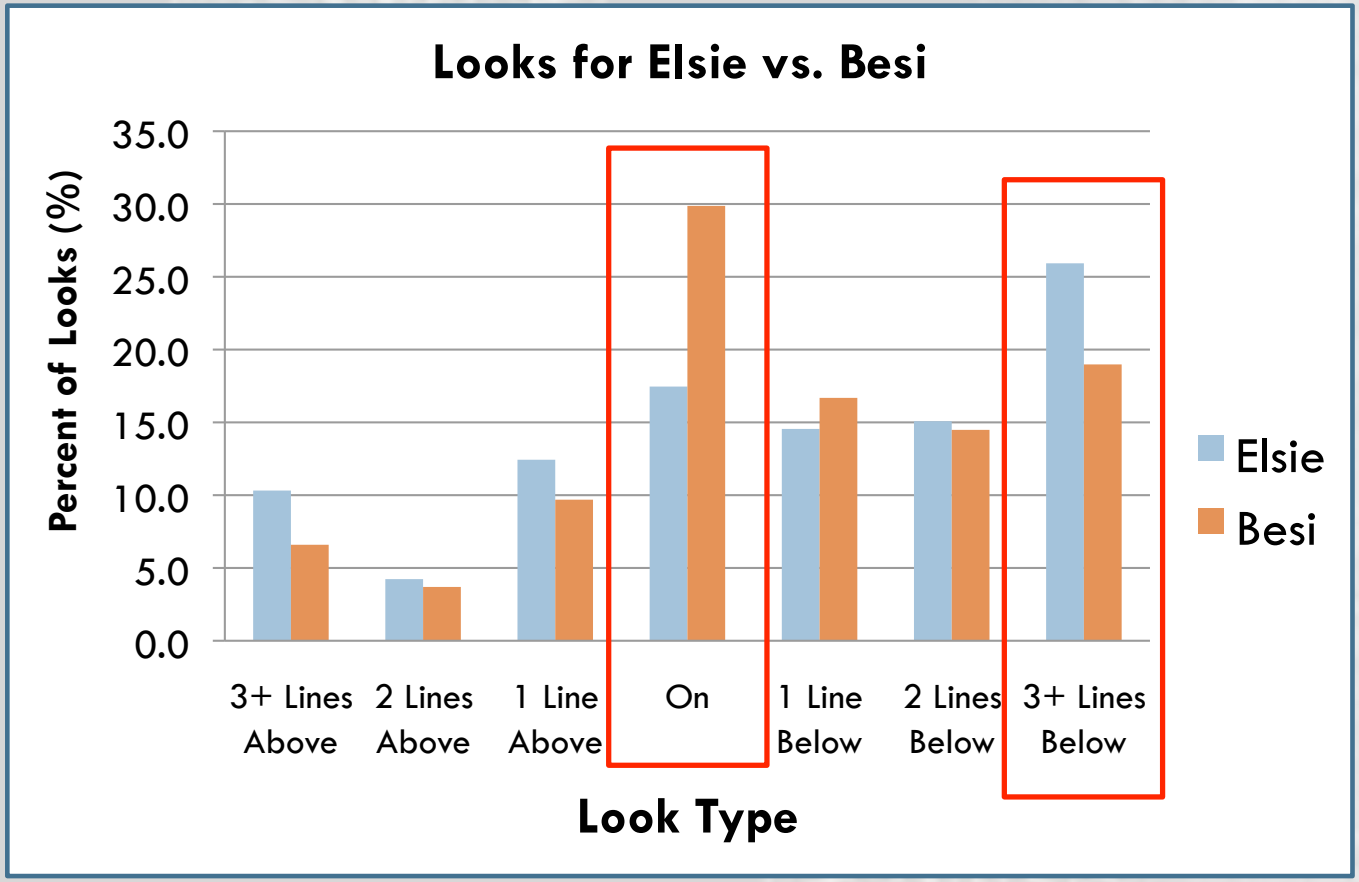

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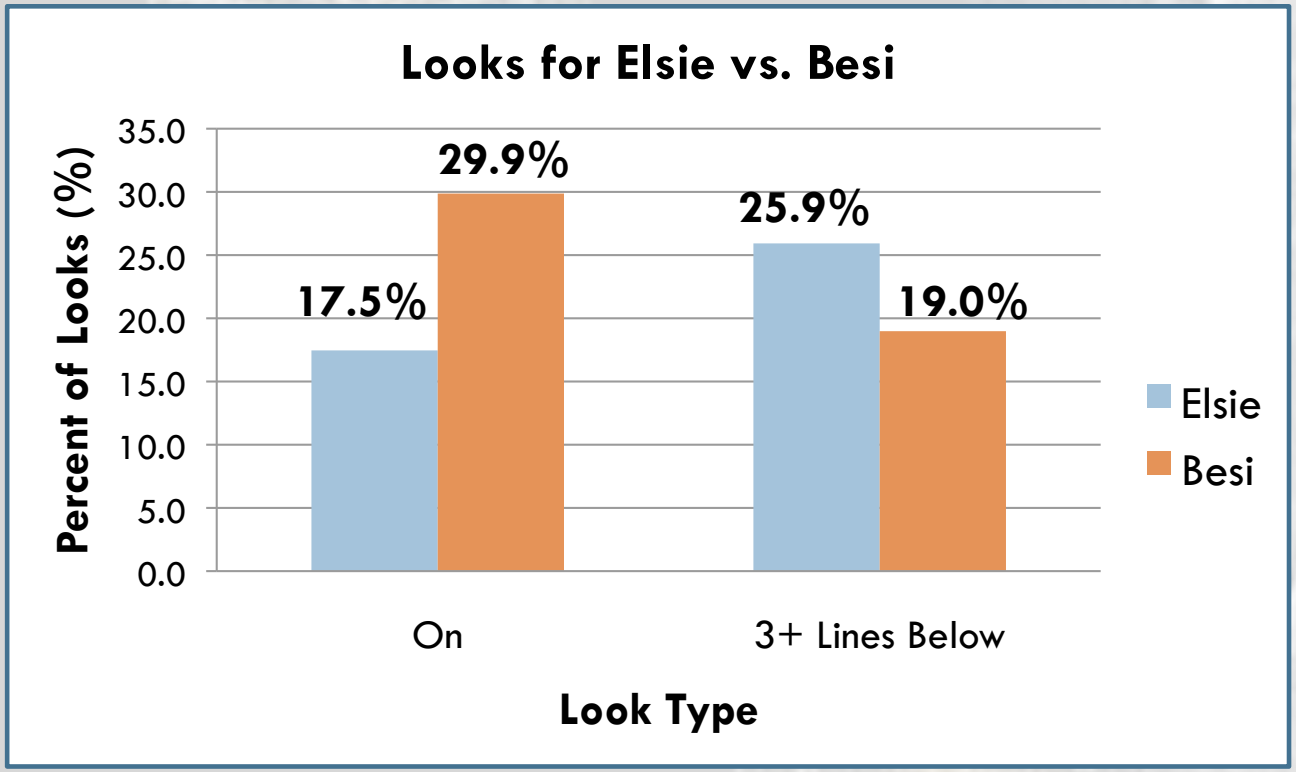


**p<0.05**

# Conclusions

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- Recommendation : Provide the entire checklist
- May not be as much need to provide entire checklist when more automated assistance is provided with the fault management task


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# Thank You!


- ISIS Lab: Robert McCann, Martine Godfroy, Ujwala Ravinder, Steve Elkins
- NASA Ames Academy: Brad Bailey, Kristina Gibbs, Doug O'Handley
- Nebraska Space Grant


Nebraska Space Grant

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# Questions?