

# **Patriot Missile Supervisory Control Study**

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16.422 13 May 2004

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# Recent Historical Events

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- **23 March 03**

- RAF Tornado GR4 shot down
- 2 aircrew killed

- **25 March 03**

- F-16 C/J “illuminated” by Patriot radar
- Fires a missile to destroy radar, no injuries

- **2 April 2003**

- USN F/A-18C shot down
- Pilot killed

# Motivation

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- Accidents attributed to “ghosting,” fictitious targets showing up on operator radar displays (1991)
  - Other Human Supervisory Control (HSC) issues
  - Even in open reports and presentations HSC issues ignored
    - E.g., “The upgraded radar which is supposed to allow crews to track and discern as many as 100 objects at a time...”<sup>1</sup>
- This study gives an analysis of the principal HSC issues surrounding Patriot missile system
  - Give a global picture of issues, stepping stone to future experiments or research in system

**Conjecture: Patriot system is a complex system that is virtually *unstudied* from a HSC viewpoint**

# Presentation Outline

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- Overview
- Supervisory Control Discussion
  - **Display layout**
    - Design issues
    - Operational issues
  - **Automation and Consent**
    - Management by consent or exception
  - **External Pressure**
    - Time
    - Life or death situation
  - **Information and Communication**
    - Studies by Adelman et.al.



**Focus of presentation**

# Patriot System

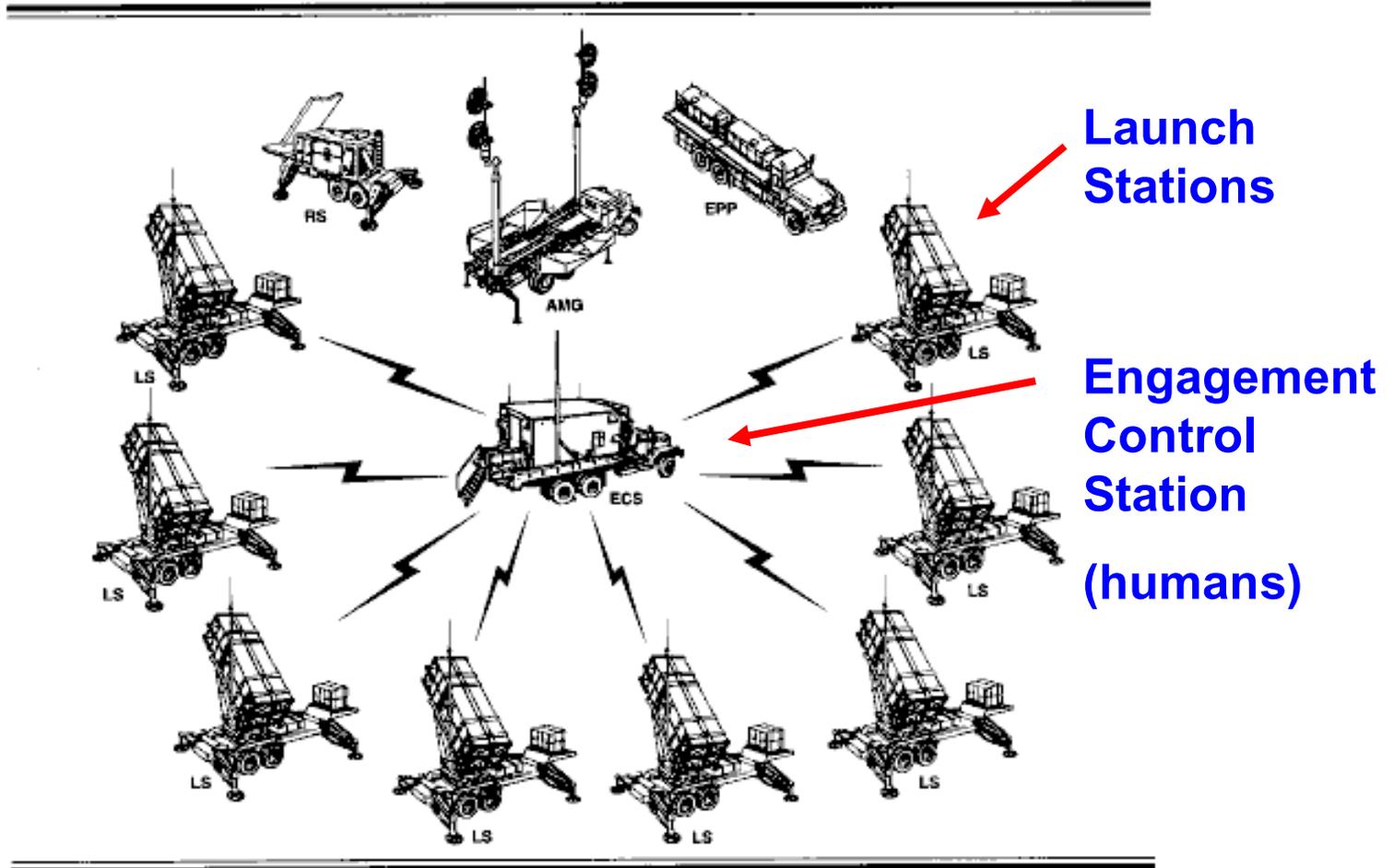


Figure B-3. Patriot fire unit.

# Patriot System

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- Crew composition<sup>1</sup>
  - Tactical Control Officer (TCO)
    - Identification
    - Engagement decision
  - Tactical Control Assistant (TCA)
    - Fires the missile
    - Aids TCO in track information
  - Operator detached from automation
  - Situational Awareness required for missile system and threat
  - Crew training
    - Simulators
  - Crew consoles

# Control Indicator Panel (CIP) Overview

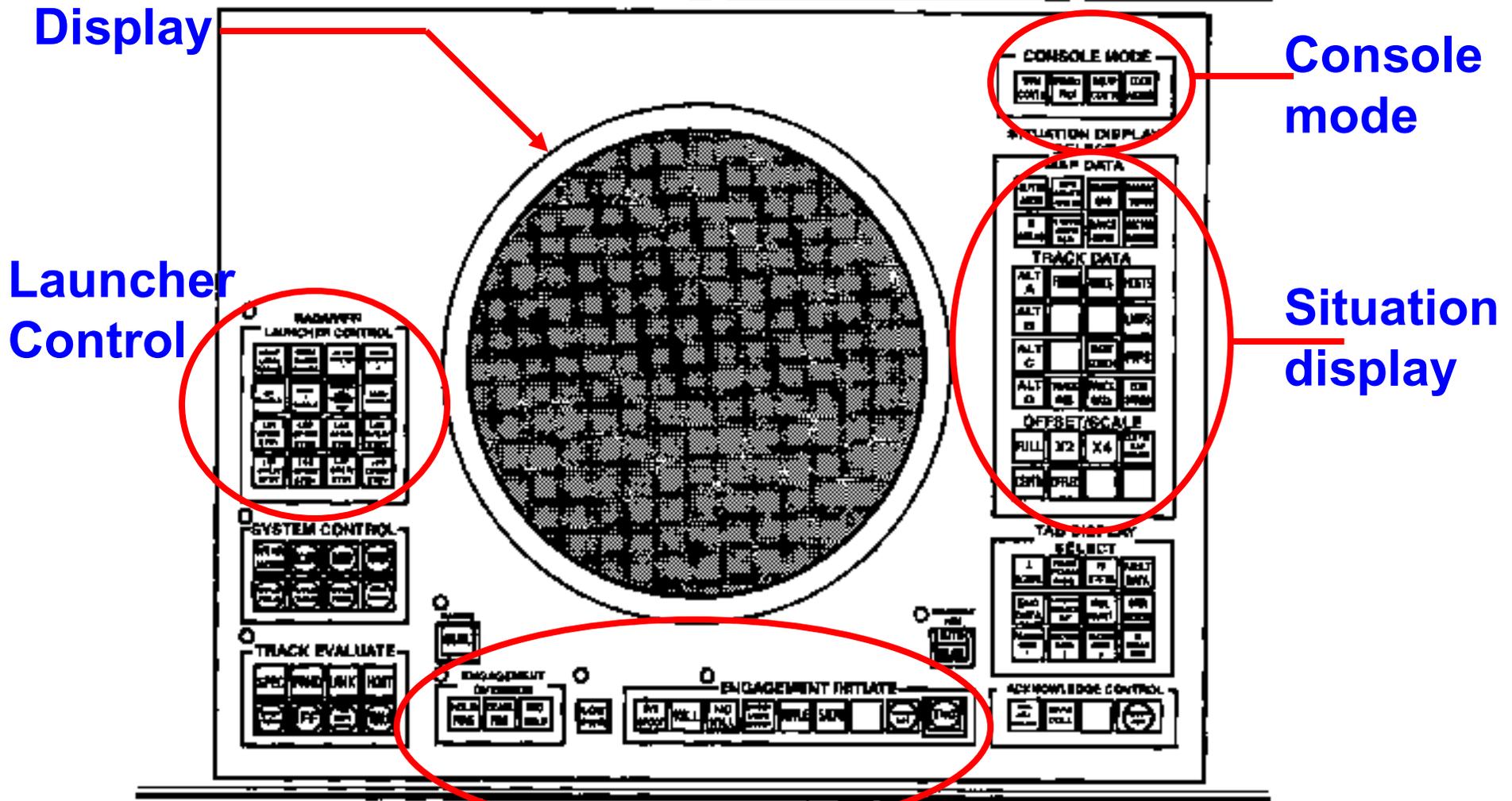


Figure 8-7. ECS control Indicator panel.

# CIP Design

- **Engage button and override**
  - In front of operator
- **Lighting coloring schemes**
  - Friendly (green)
  - Unknown (amber)
  - Hostile (red)



*STARS Display*



- **Clutter**
  - Missile status display below map display, monochrome
- **Size and Shape**
  - Display estimated at 15in radius, circular
- **Panel Arrangement**
  - Empty space for larger display?

# CIP Design

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- **“Operational” Clutter**

- Defended areas
- Weapon control areas
- Masked terrain
- Launch now intercept points, predicted intercept
  - Available on CIP

- **Situational Awareness**

- Battlefield situation
- Aircraft flying in and out of “engagement zones”
- Threat
- Lack of immediate feedback



*Older CIP*

- **Technology improves, display does not...**

- **False Targets (ghosting)**

- False alarms
- Not trained for in CIP simulators

# Examples of CIP Display

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See image at

[http://www.globalsecurity.org/space/library/report/2004/patriot-shot-friendly\\_20apr2004\\_apps1-2.pdf](http://www.globalsecurity.org/space/library/report/2004/patriot-shot-friendly_20apr2004_apps1-2.pdf)

# Automation and Consent

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- **Patriot operators act as ATC controllers and nuclear plant operators**
  - Need to maintain SA about air traffic, but cannot **directly control** the traffic
  - **Wait** for event which requires *precise and quick* response
    - Vigilance
- **Target engagement process**
  - Launch detection by radar; AWACS, PAWS, Cobra Judy, **and** others (!) generally contribute to providing information **[20 sec]**
  - TCO verifies launch, expected impact point (if missile) via impact ellipse, positive ID on target (IFF) on CIP; TCA assists in ID **[10-60 sec]**
  - Launch station selected, data uploaded to missile **[20 sec]**
  - Missile launch

# Automation and Consent

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- Identification Friend or Foe
  - Identifies friendly or unfriendly aircraft, challenge-response
  - IFF ID:
    - Patriot crew query aircraft
    - If unknown, can query system for flight track history (on CIP)
    - AWACS, and other sources (if functioning)
- Trust
  - “The Patriot...can shoot down anything that flies” (TCO)<sup>1</sup>
  - “Intercept rate...possibly even 0%” (Prof. Postol, MIT)
- Management by Consent/Exception
  - Semi-Automatic
    - Automation queries, crew responds; less timely, more human information processing
  - Automatic → **Shoot-downs believed to be in this mode**
    - System automatically engages without crew input; timely, less human information processing

# External Pressures

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- Time
  - Al Hussein missile: 6-7 minute TOF
  - Al Samoud missile: **3-4** minute TOF
- Fear
  - “Fog of war”
  - Induced by information of NBC attack, prior information
  - Partially emphasized by ECS Status Panel (shown next)
  - Automatic vs. Semi-Automatic
  - Yet, **0** Patriot crews killed in combat
- Missed Detections and False Alarms are *both* expensive
  - *Not* launching a missile could result in numerous deaths, 1000s
  - *Launching* a missile could result in shooting down a friendly aircraft, <10 deaths

# External Pressure

Defense Condition      Weapon control

Attack warnings

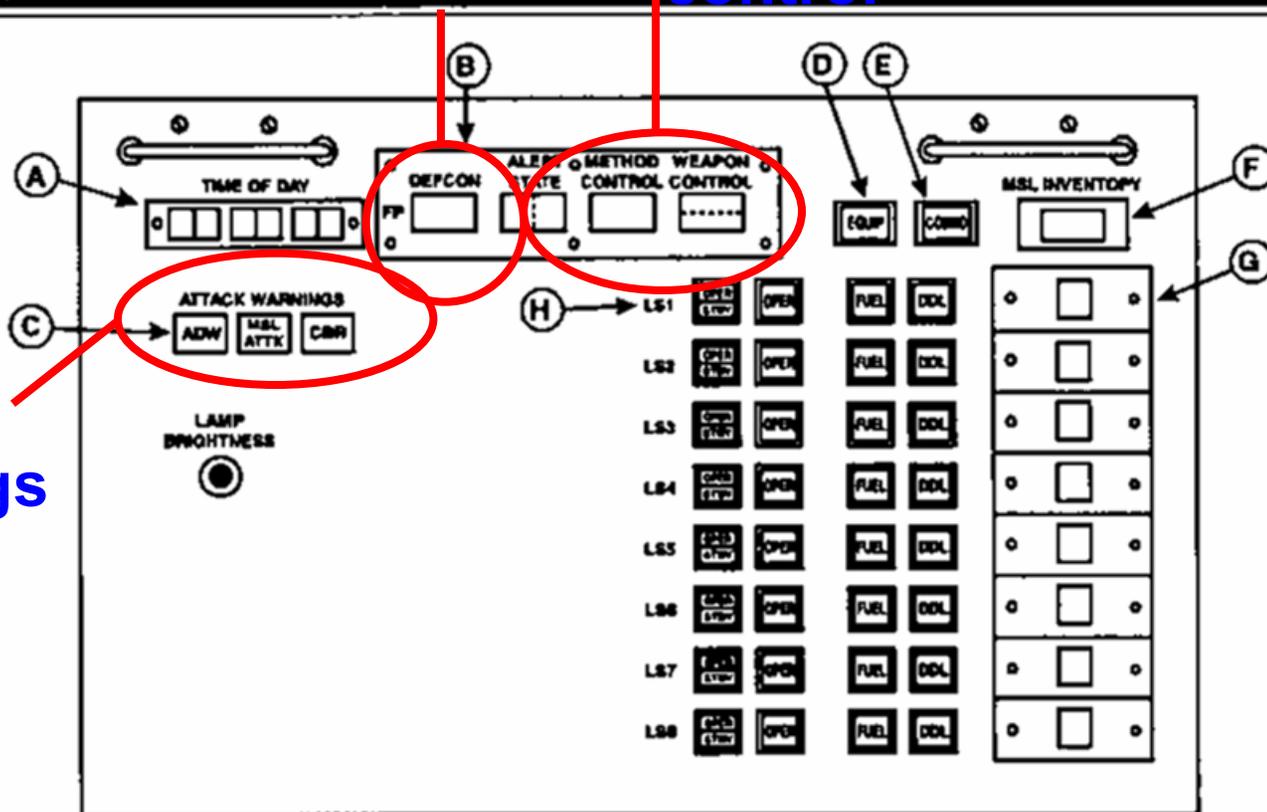


Figure B-9. ECS status panel.

## QUESTION

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If there is a problem with the radar, why do the crews still put the system in automatic mode???

# Signal Detection Theory

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(Image removed due to copyright considerations.)

# Signal Detection Theory

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- Signal Detection Theory *mismatches* with actual events
  - SDT approach to the “ghosting effect”
  - Placing missiles in automatic mode
- Crews seemingly do *not*
  - Change their threshold
  - Lose trust in the system
    - The loss of aircrew not comparable to the loss of thousands of civilians?
- **Conjecture:** SDT does *not seem* to describe Patriot crew situation completely
- Possibility
  - Mismatch between crew SOC model and true SOC model???
  - Time, pressure must be included in overall model

*Note: Overall system not considered here, only detection*

# Conclusion

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- Patriot is *extremely* complex system
- Some inherent technical difficulties that are still being worked on, BUT...
  - Numerous HSC issues *not* addressed in open literature
- Recommendations of this case study
  - 1. Display design**
    - Expensive to redesign or retrofit
    - Beneficial to take examples from ATC
  - 2. Understand better role of battlefield pressure and ghosting on crew**
    - Will help in display design
    - Less expensive to do if crew trained, software fixed
  - 3. Understand Patriot crew model of the system**

## References

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1. US Army Field Manual 44-85 (<http://www.fas.org>)
2. Lecture notes by Prof. Ted Postol (<http://www.globalsecurity.org>)
3. BBC
4. Wickens, C.D. and J. Hollands. *Engineering Psychology and Human Performance*. Prentice-Hall, 1999.
5. Kuchar, J. *Lecture Notes*, 2002.