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Situation Awareness for Supervisory Control – Revisiting the Vincennes Incident

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15th International Command & Control Research & Technology Symposium
22-24 June 2010 (Santa Monica, California)

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Synopsis

- Establish that **situation awareness (SA) is different for "on" *vs* "in"** the loop
  - Supervisory Control = "on" the loop
- Revisit the Vincennes Incident using "on" *vs* "in" the loop models
  - **Identify specific failures in C^2 design** across the human-machine system
- C^2 design principles for "on" the loop SA
  - Design space that awaits exploitation

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Outline

- Supervisory Control
  - Intelligent agents and the “loop”
- Situation Awareness (SA)
  - SA “in” *vs* “on” the loop
- Vincennes Incident Revisited
  - C^2 system failed to support humans in their “on” the loop role
  - Design principles for “on” the loop systems
- Implications for C^2 Theory and Practice

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Supervisory Control

- Sheridan Model of *Supervisory Control*

  "One or more human operators are intermittently programming and continually receiving information from a computer that itself closes an autonomous control loop through artificial effectors to the controlled process or task environment."

- *Informally*: "on" the loop
  - Versus human being "in" the control loop

T B Sheridan, *Telerobotics, Automation, and Human Supervisory Control*, Cambridge: MIT Press, 1992.

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Relevance to Evolution of C^2

- Vincennes Incident (1988)
  - US Navy warship downed Iranian Airbus
  - Prompted Tactical Decision Making Under Stress (TADMUS) research program

  but

  - Framed under “in” the loop thinking
- Supervisory control is USAF preferred C^2 concept for future unmanned systems
  - C^2 design to support processes and behaviours of supervisory control?

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Intelligent Agents

- AI definition of *Intelligent Agent*

  "Autonomous entity that observes and acts upon an environment and directs its activity towards achieving goals."

- No restrictions on an agents' construction
  - Humans, machines, organisations, …

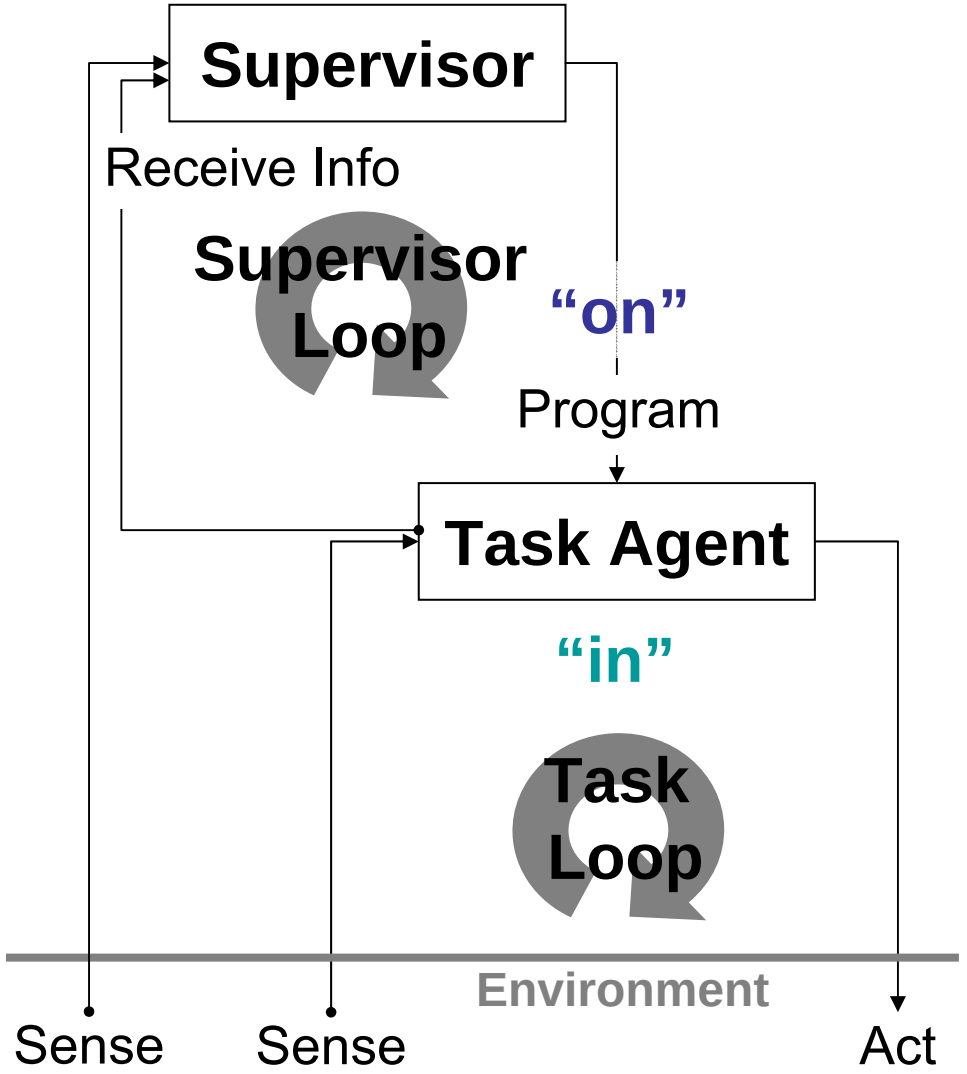
- Reconstruct *Supervisory Control* as

  "One or more operators are intermittently programming and receiving information from an artificial intelligent agent."

S J Russell, P Norvig, *Artificial Intelligence: A Modern Approach*, 2nd Edition ed., Upper Saddle River, NJ: Prentice Hall, 2003.

Task and Supervisor Agents

- Task Agent
  - Sense & Act into environment
- Supervisor Agent
  - Sense from environment
  - Receive Info from Task Agent
  - Program Task Agent



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Lethal Agents

- Lethal Agent
  - Particular form of Task Agent
  - Closes a firing loop from sensors to weapons

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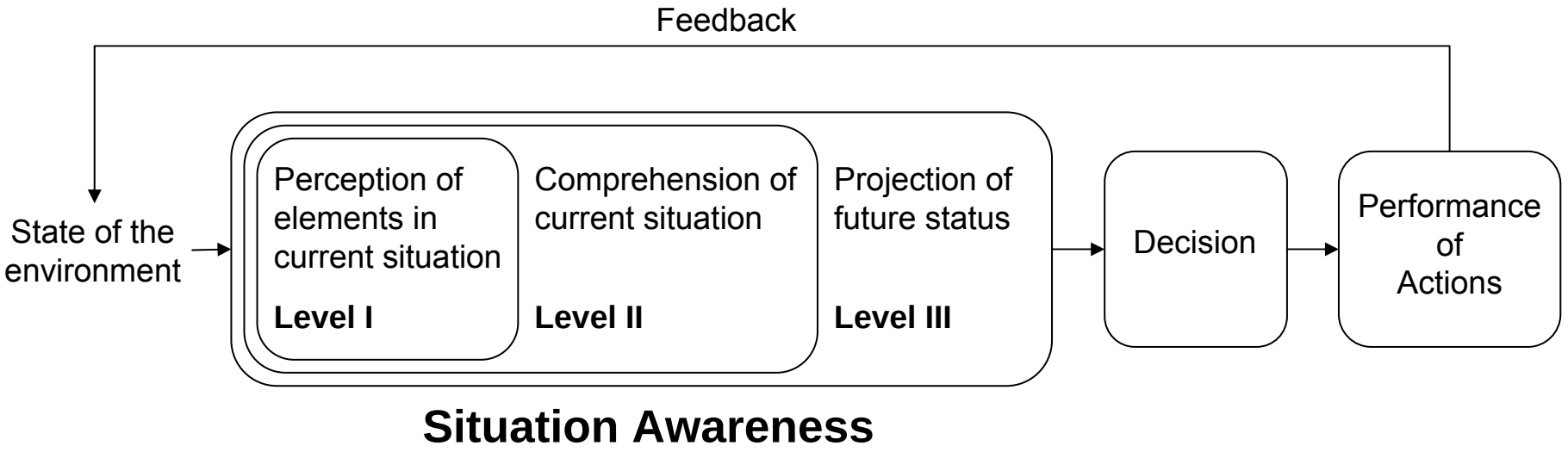
Situation Awareness

- Endsley model of *Situation Awareness*

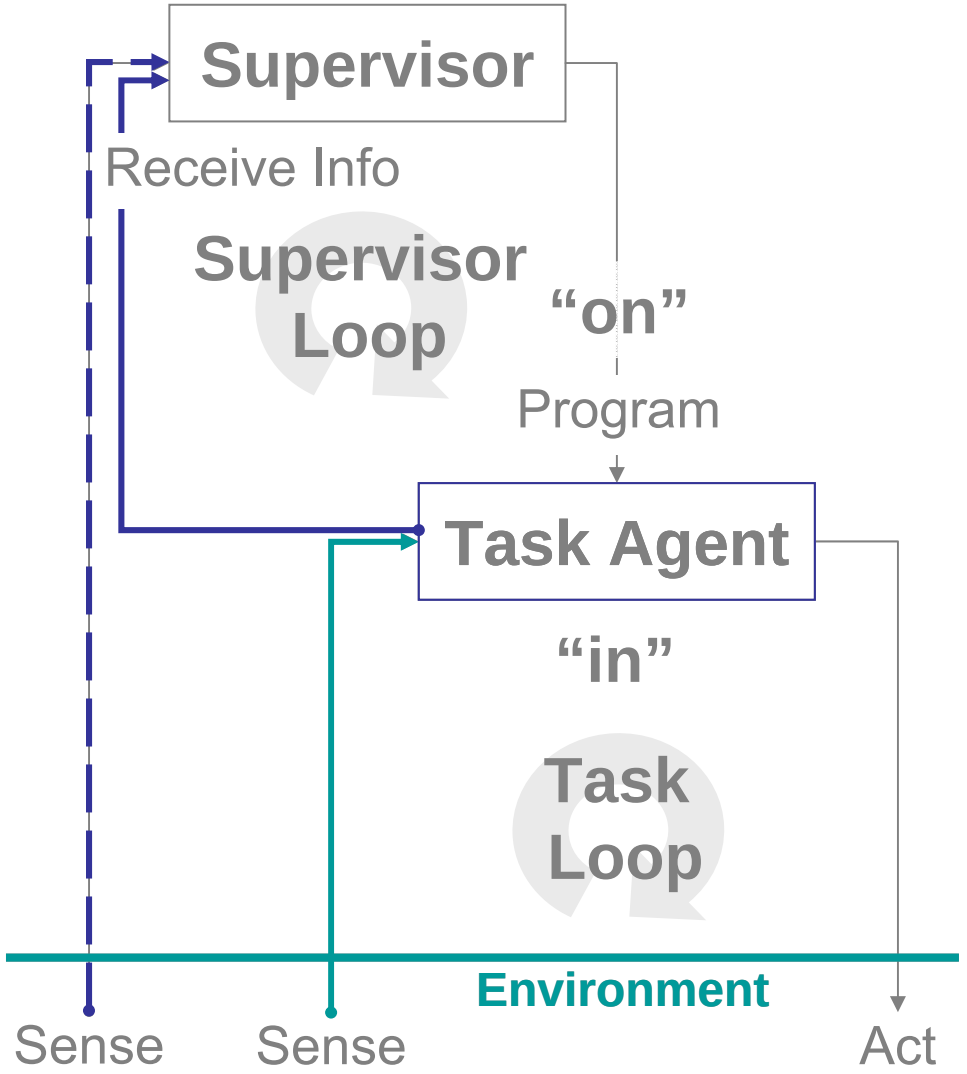
  "The perception of the elements in the environment within a volume of space, the comprehension of their meaning and the projection of their status in the near future."



M R Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," *Human Factors*, 37(1), 1995, 32-64.

"Volume of space"

- Task Agent
  - "volume of space" is the external world
- Supervisor Agent
  - "volume of space" is the state space of the Task Agent
  - Sense from external world to calibrate the Task Agent



Vincennes Incident

- *USS Vincennes* shot down Iranian Airbus
  - State-of-the-art air warfare combat system (Aegis)
  - Highly-trained crew, considered fully-capable

- Questions for analysis:
  - Where were the “on” *vs* “in” the loop activities?
  - Were the humans supported in these activities?

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USS Vincennes

***USS Vincennes*, 24-Oct-1988**

USS Vincennes

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SPY-1 Surveillance & Control Radar

- Detect & track contacts, guide weapons

UPX-29 Interrogation Friend or Foe

- Interrogate transponder on contacts

Air-Ground-Air Radio

- Talk to aircraft via A-G-A communication frequencies

SPG-62 Fire Control Radar

- Illuminate targets for SARH missiles

SM-2 Surface-to-Air Missile

- Mid-course guidance with Semi-Active Radar Homing

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USS Vincennes

Combat Information Center
***USS Vincennes*, 1-Jan-1988**

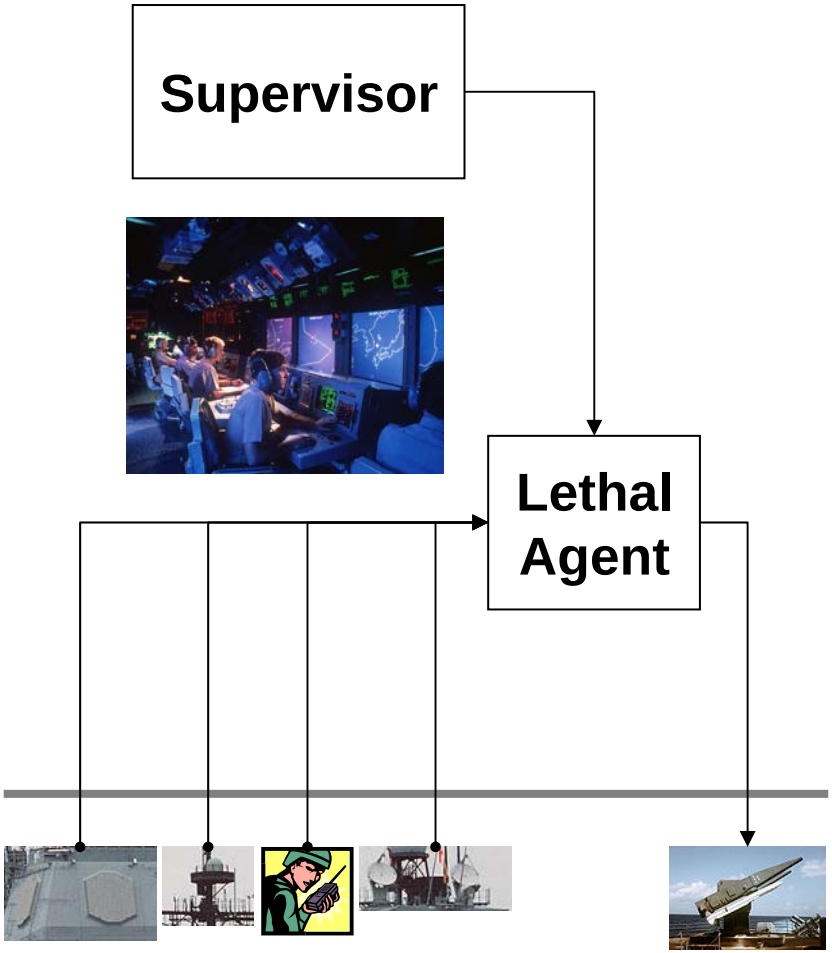
Timeline

1017	Iran Air Flight 655 departs Bandar Abbas. Acquired by SPY-1 radar.	Reported as TN4474. Later renumbered to TN4131.
	Interrogated by UPX-29, which saw IFF Mode III (Civilian).	
1018	Identification Supervisor consulted COMAIR schedule, concluded that contact was *not* Iran Air Flight 655.	Flight 655 was running 27 min late.
1019 1020	TN4131 3–4 Nm off COMAIR centre. Challenged over Military Air Distress Channel. Start multiple challenges on International Air Distress Channel.	No way of knowing whether radio calls had been received.
1020	UPX-29 reports IFF Mode II (Military). Identification Supervisor reports possible F-14. Own Ship Display Assistant updates screens used by Commanding Officer (CO) and Tactical Action Officer (TAO).	UPX-29 was not actually interrogating the Airbus. IFF “hooked” to TN 4131 symbol, but UPX-29 was actually interrogating the vicinity of Bandar Abbas.

Timeline

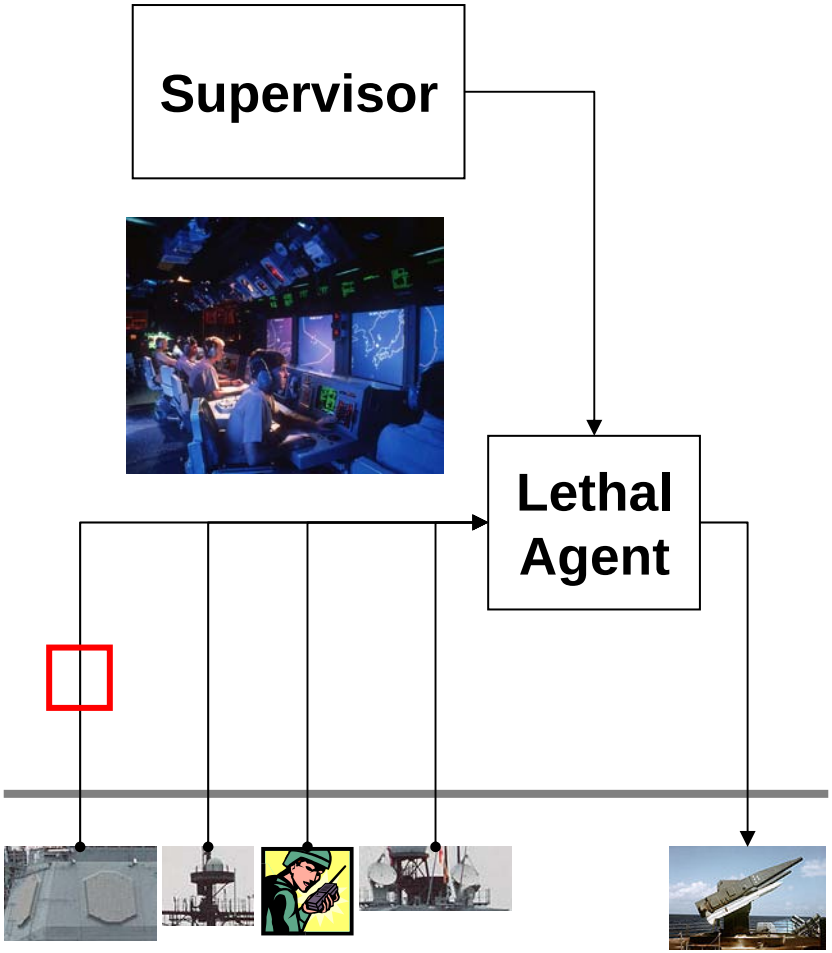
1022	Contact crosses 20 Nm threshold. Illuminated with SPG-62.	Civilian aircraft not equipped to detect fire control radars.
	CO asked for status on “TN4474”.	TN4474 had been reassigned to an A-6 Intruder, then descending and accelerating.
	USS Sides notes TN4131 continuing to climb. CO *Sides* evaluates TN4131 as non-threat.	TAO *Side* unable to gain attention of TAO *Vincennes*. CO *Sides* does not pass on evaluation.
1023	CO *Vincennes* searching for emissions to help identify “unknown-assumed hostile” contact.	Had acknowledged earlier comment that the contact may have been a commercial airliner.
1024	CO *Vincennes* orders launch of two SM-2 missiles.	

Agents and Behaviours



- Lethal Agent and Supervisor were assembled from *Vincennes* systems and crew members
- C^2 system failed to support the Supervisor, as seen in key events leading to the fratricide

Agents and Behaviours



- CO asked for TN4474
  - "Dangling pointer" error
- **C^2 Design Principle**
  - Support the Supervisor to track & debug errors in the Task Agent

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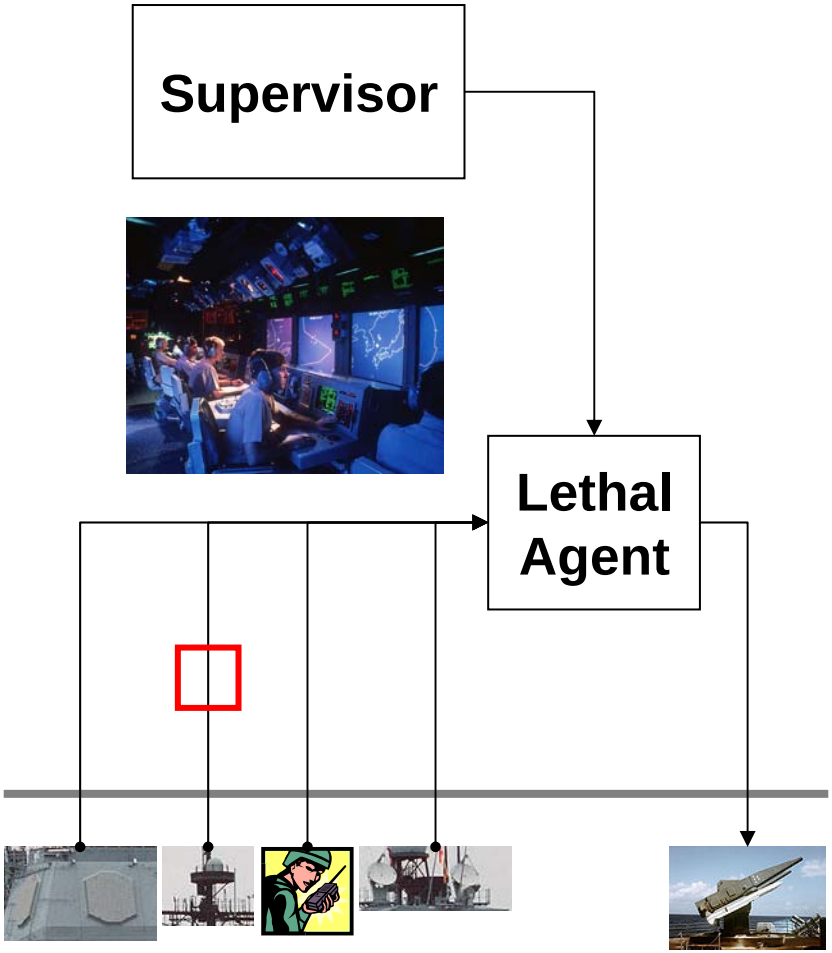
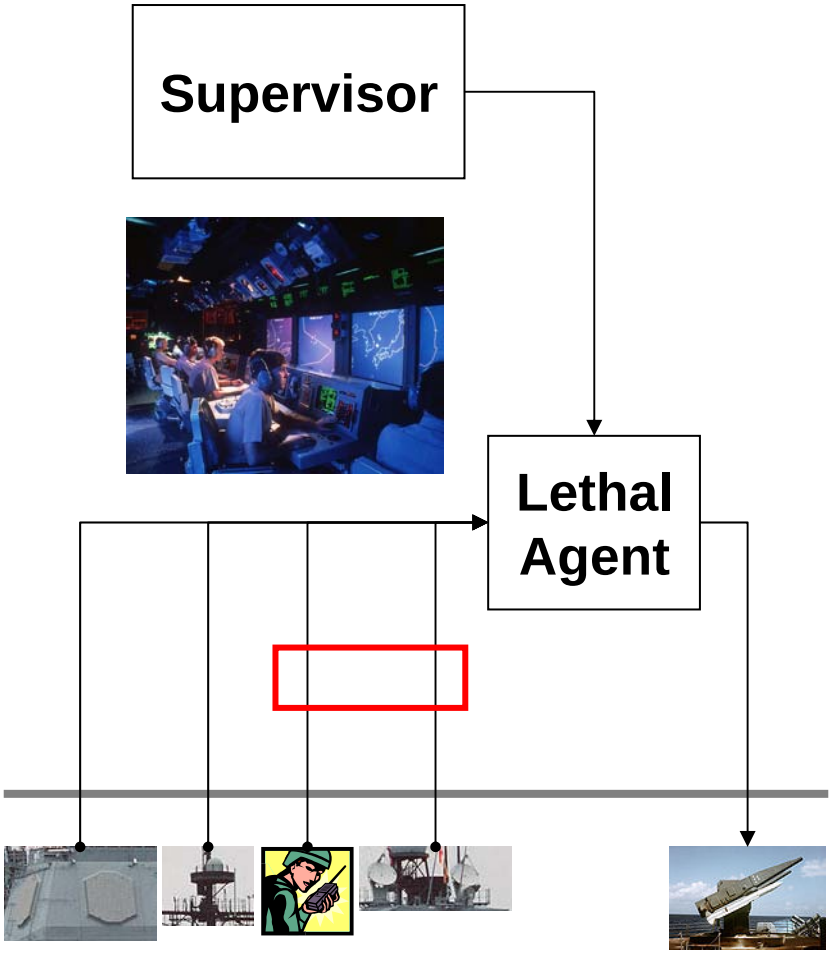
Agents and Behaviours



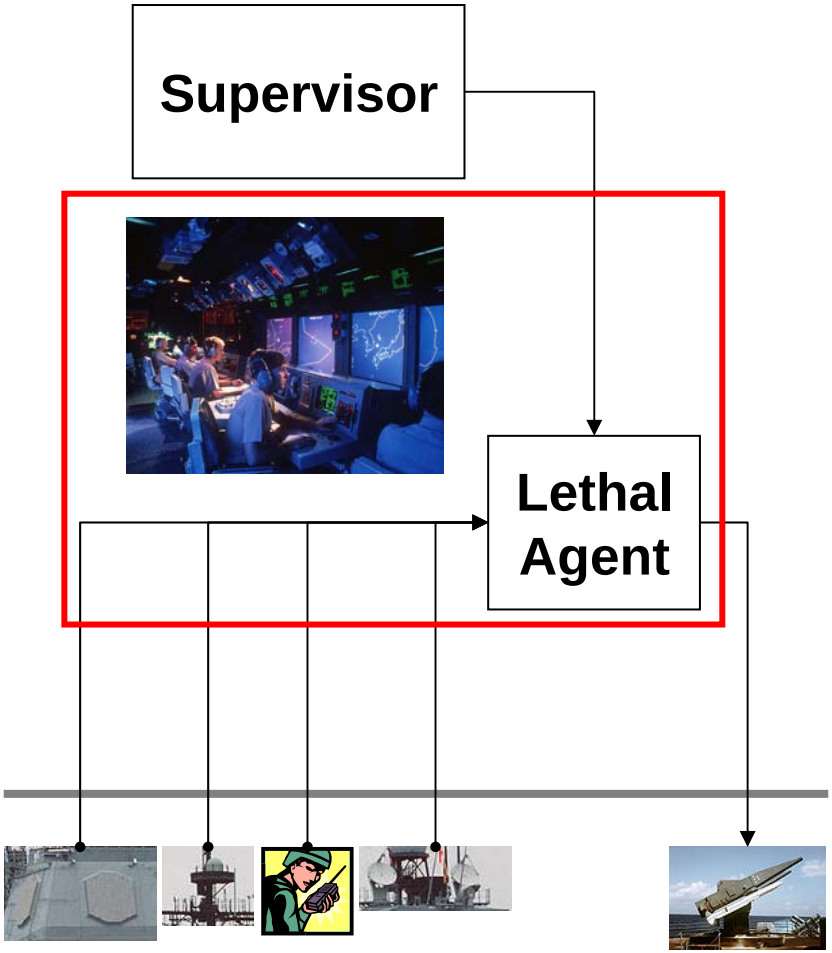
- UPX-29 was not interrogating Airbus
  - Error in how equipment was being used
- **C^2 Design Principles**
  - Transporting and summarising info is *not* supervisory control
  - Checking how info is gathered and used *is* supervisory control

Agents and Behaviours



- Airbus did not respond to radio calls nor fire-control radars
  - Error in formulation of Rules of Engagement
- **C^2 Design Principles**
  - Make the Task Agent's program explicit
  - Help Supervisor to predict the Task Agent's behaviour

Agents and Behaviours



- Who was supervising?
  - Lethal Agent employed everyone up to and including the CO
- **C^2 Design Principles**
  - Supervisor is a distinct role, with its own “loop”
  - Avoid double-hatting of personnel to both “in” and “on” the loop

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Implications for C^2

- SA researchers should look for the loops, irrespective of composition or tempo
  - The Supervisory Control loop is somewhere … trace the info flows ("on" the loop SA)
  - Very slow loop ≠ No loop
- C^2 designers must recognise the Supervisor
  - Distinct activities and information
  - Distinct role with its own workload
  - Not a new requirement, was always present *but* neither recognised nor addressed

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Conclusions

- Established that **situation awareness (SA) is different for "on" *vs* "in"** the loop
  - Supervisory Control = "on" the loop
- Key events in Vincennes Incident **can be traced to failures in supervisory control**
  - C^2 design failed to foster "on" the loop SA
- Future C^2 systems ought to recognise the needs of supervisory control
  - Proposed some design principles