



# Using a Crew Resource Management Framework to Develop Human-Autonomy Teaming Measures

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# HAT Measure Benefits

- System Design
  - Use measure categories to ensure coverage of teaming behavior
- Scenario Development
  - Use behavioral markers of measures to develop scenarios to elicit performance
- System Evaluation
  - Use markers to test performance

# NOTECHS CRM

Category	Element	Behavior
Cooperation	Considering others	Consider condition of other
	Supporting others	Offer assistance
Management/ Leadership	Authority/Assertiveness	Take Initiative
	Maintain standards	Enforce SOP
	Planning/Co-ordinating	State plan
	Workload management	Distribute tasks
Situation Awareness	System awareness	Monitor/report system (incl. other crew)
	Env awareness	Monitor/report env
	Awareness of time (anticipation)	Monitor/report time constraints
Decision Making	Problem diagnosis	ID problem
	Option generation	Generate/elicit options
	Option selection	Select option
	Outcome review	Review outcome

# NATO Patterns



***Human***



***Agent*** (create own situation awareness, make decisions,  
plan course of action)



***Supervisory Relationship*** (e.g., delegation)



***Cooperative Relationship*** (e.g., assistance)

# Patterns +CRM



*Human*



*Agent*

M1-10/S1-3/D1-4

*Management: Take initiative (Sheridan levels)*

*SA: Perceive, Comprehend, Project (Endsley levels)*

*Decision Making: ID problem, Generate options,  
Select option, Review outcome*



*Supervisory Relationship*

*Management: Command*

*SA: Monitor*



*Cooperative Relationship*

*Cooperation: Consider condition, Offer assistance*

*Management: State Plan, Distribute tasks*

*SA: Monitor/crosscheck*

*Decision Making: Elicit options*

# Agent Measures

## ***Situation Awareness (Endsley)***

- 1) Perceive***
- 2) Comprehend***
- 3) Project***

## ***Decision Making (NOTECHS)***

- 1) ID problem***
- 2) Generate options***
- 3) Select option***
- 4) Review outcome***

## **Management (Sheridan)**

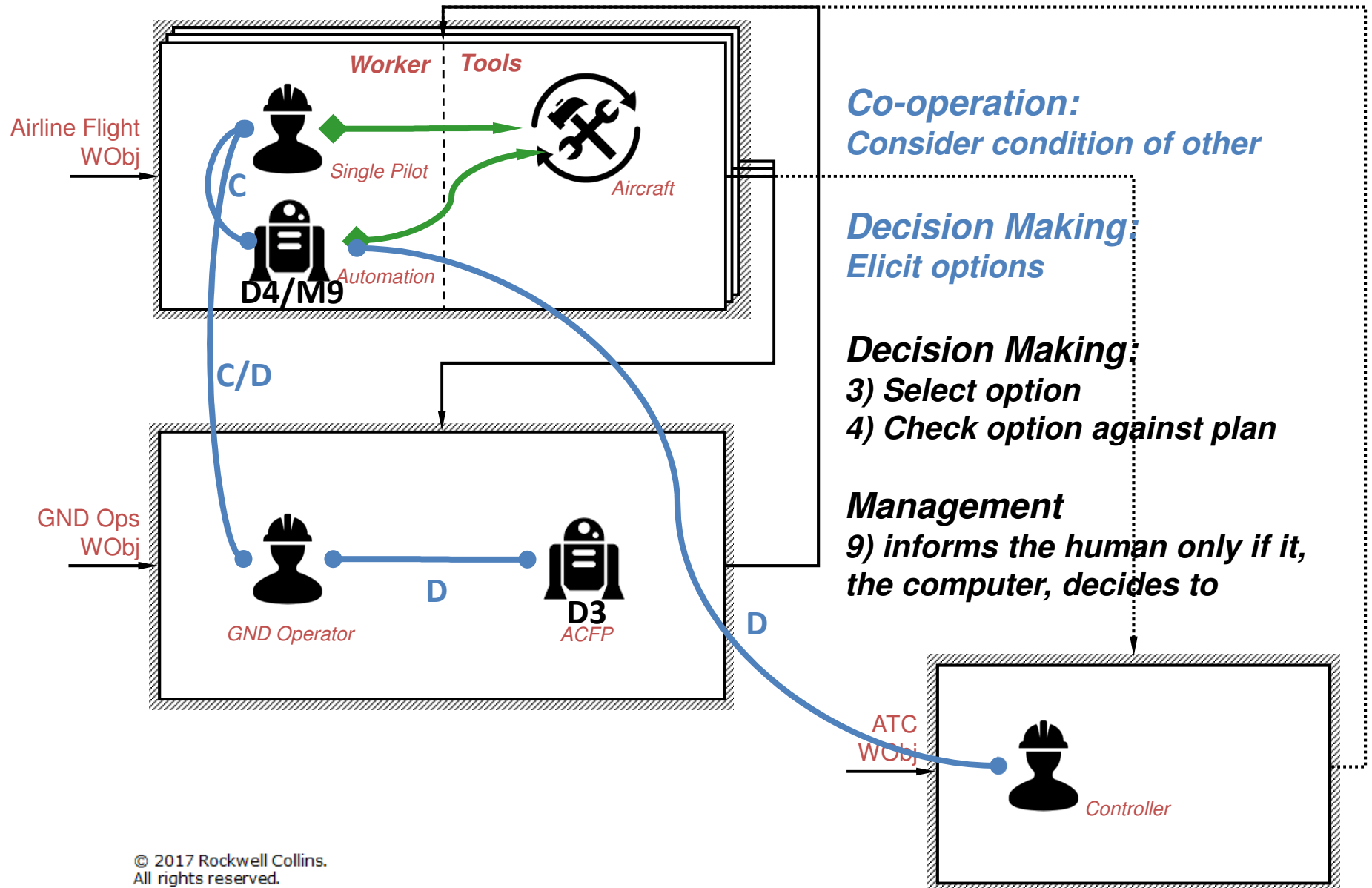
- 1 The computer offers no assistance:  
human must take all decision and actions.
- 2 The computer offers a complete set of  
decision/action alternatives, or
- 3 narrows the selection down to a few, or
- 4 suggests one alternative, and
- 5 executes that suggestion if the human approves, or
- 6 allows the human a restricted time to veto  
before automatic execution, or
- 7 executes automatically, then necessarily  
informs humans, and
- 8 informs the human only if asked, or
- 9 informs the human only if it, the computer, decides to.
- 10 The computer decides everything and acts  
autonomously, ignoring the human.

# SPO Use Case

NASA123 SFO - BOS. One pilot on board (POB), dispatch/flight following on ground (GO)

- On board automation detects fuel imbalance - alerts POB and GO
- POB requests automation diagnose fuel imbalance
- Automation reports (to POB) a leak in left forward tank
- POB requests automation to manage fuel
- POB contacts GO about need to divert
- GO requests divert planning from ACFP
- ACFP returns FP to GO
- GO uplinks FP to POB
- POB requests automation coordinate divert with ATC
- Automation reports divert is approved
- POB tells automation to execute

# SPO Design

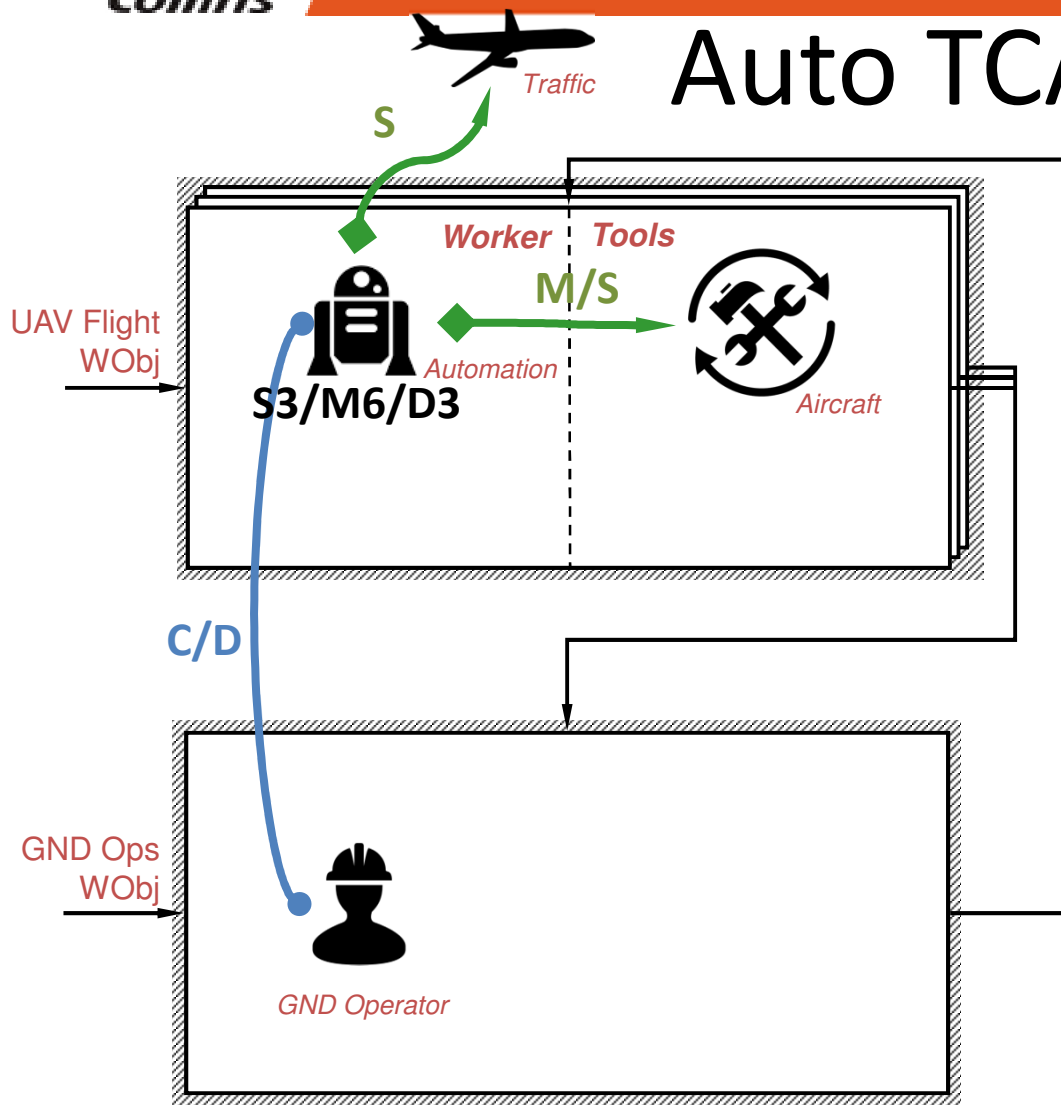




# Auto TCAS Use Case

- Ground Operator is supervising UAS
- UAS TCAS detects traffic and provides avoidance option
- Operator does not react in time
- UAS implements option

# Auto TCAS Design



**Management**  
**Command**  
**SA**  
**Monitor**

**Cooperation:**  
*Consider condition of other*

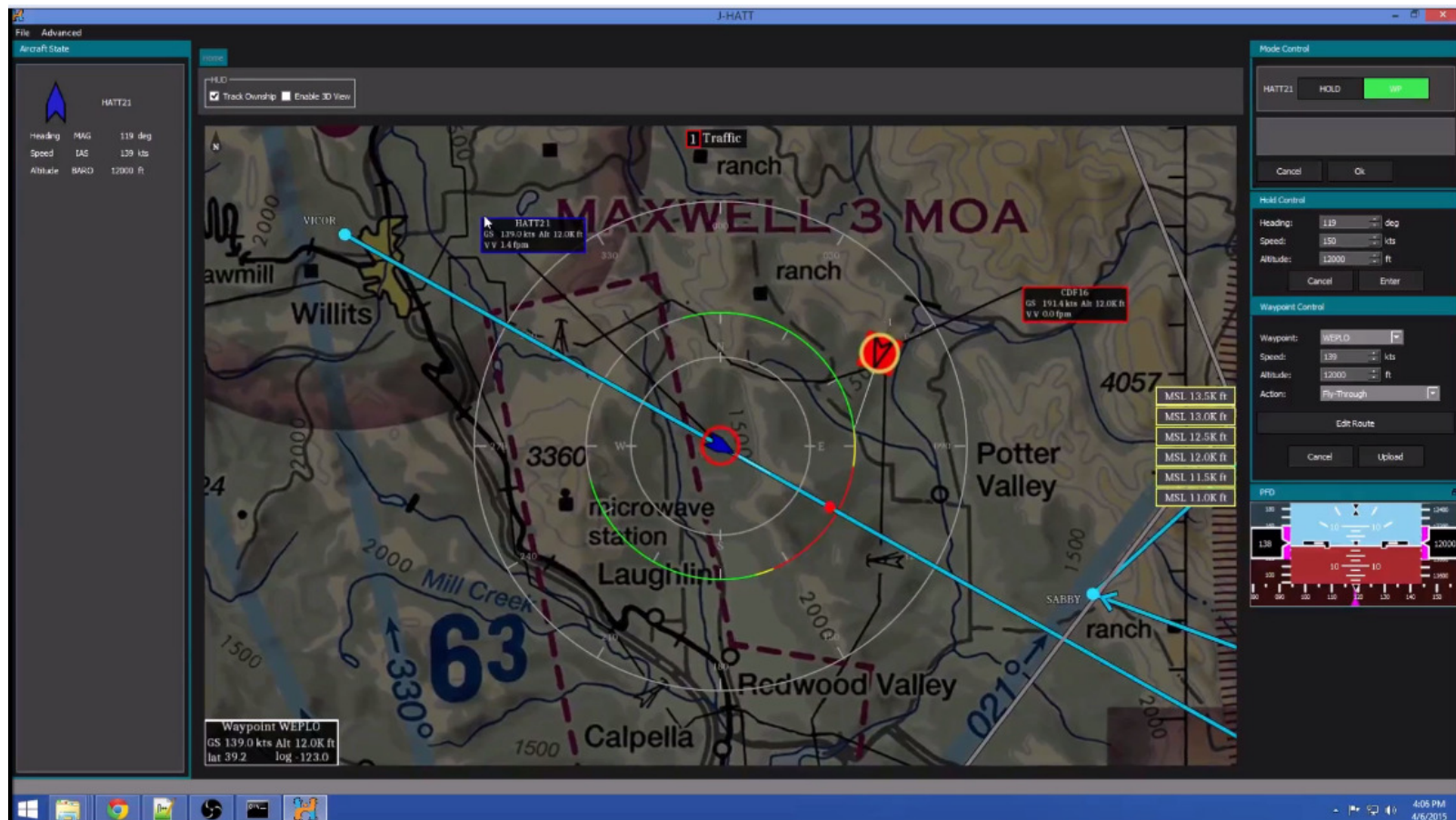
**Decision Making:**  
*Elicit options*

**Situation Awareness**  
**3) Project**

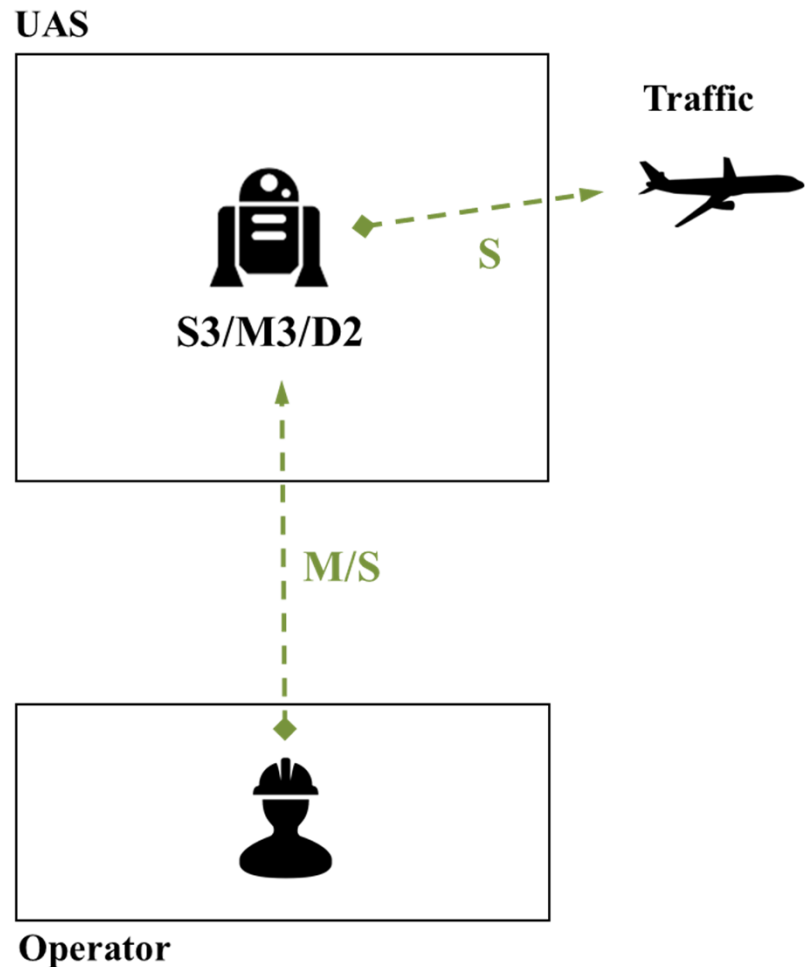
**Management**  
**6) allows the human a restricted time to veto before automatic execution**

**Decision Making**  
**3) Select option**

# NASA UAS Ground Station



# UAS Evaluation



*Management  
Command  
SA  
Monitor*

*Situation Awareness  
3) Project*

*Management  
3) narrows the selection  
of options down to a few*

*Decision Making  
2) Generate options*

UAV detects conflict and provides avoidance arc

# Agent and Relationship Measures



M1-10/S1-3/D1-4

## Agent

**Management:** Take initiative (Sheridan levels)

**SA:** Perceive, Comprehend, Project (Endsley levels)

**Decision Making:** ID problem, Generate options,  
Select option, Review outcome



M/S

## Supervisory Relationship

**Management:** Command

**SA:** Monitor



C/M/S/D

## Cooperative Relationship

**Cooperation:** Consider condition, Offer assistance

**Management:** State Plan, Distribute tasks

**SA:** Monitor/crosscheck

**Decision Making:** Elicit options

# Agent Measures

## ***Situation Awareness (Endsley)***

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**M1-10**

**S1-3**

**D1-4**

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# Next Steps

- Apply measures to more use cases
- Use measures to drive improvements to NASA autonomy projects

**QUESTIONS?**

# Situation Awareness

**Perception (Level 1 SA):** The first step in achieving SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. Thus, Level 1 SA, the most basic level of SA, involves the processes of monitoring, cue detection, and simple recognition, which lead to an awareness of multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions).

**Comprehension (Level 2 SA):** The next step in SA formation involves a synthesis of disjointed Level 1 SA elements through the processes of pattern recognition, interpretation, and evaluation. Level 2 SA requires integrating this information to understand how it will impact upon the individual's goals and objectives. This includes developing a comprehensive picture of the world, or of that portion of the world of concern to the individual.

**Projection (Level 3 SA):** The third and highest level of SA involves the ability to project the future actions of the elements in the environment. Level 3 SA is achieved through knowledge of the status and dynamics of the elements and comprehension of the situation (Levels 1 and 2 SA), and then extrapolating this information forward in time to determine how it will affect future states of the operational environment.

# Cooperation

Element	Good practice	Poor practice
<b>Team building and maintaining</b>	Establishes atmosphere for open communication	Blocks open communication
	Encourages inputs and feedback from others	Keeps barriers between crewmembers (CM)
	Does not compete with others	Competes with others
<b>Considering others</b>	Takes notice of the suggestions of other CM even if s/he does not agree	Ignores suggestions of other CM
	Takes condition of other CM into account	Does not take account of the condition of other CM
	Gives personal feedback	Shows no reaction to other CM
<b>Supporting others</b>	Helps other CM in demanding situations	Hesitates to help other CM in demanding situations
	Offers assistance	Does not offer assistance
<b>Conflict solving</b>	Keeps calm in interpersonal conflicts	Overreacts in interpersonal conflicts
	Suggests conflict solutions	Sticks to own position without considering a compromise
	Concentrates on what is right rather than who is wrong	Accuses other CM of making errors

# Behavioral Markers

- The term behavioral markers refers to a prescribed set of behaviors indicative of some aspect of performance (Flin & Martin, 2001)