Human Autonomy Teaming Measures

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Rockwell Collins

Space Act Agreement with NASA Ames HAT Lab

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Human-Autonomy Teaming

• How can autonomy best work with humans?
  – Have the qualities of a good team member
• How can these qualities be measured?
  – Use human teaming measures
  – Crew Resource Management
## NOTECHS CRM

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Flin et al. (2003)
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Flin et al. (2003)
NATO Patterns

Human

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

Supervisory Relationship (e.g., delegation)

Cooperative Relationship (e.g., assistance)

NATO HFM-247 (2015)
Patterns + CRM

**Human**

**Agent**

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

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

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

Human

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Management: Take initiative (Sheridan levels)

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M1-10/S1-3/D1-4
Patterns + CRM

**Human**

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**Supervisory Relationship**

**Management:** Command

**SA:** Monitor

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Patterns + CRM

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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
Patterns + CRM

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Agent Measures

Situation Awareness (Endsley)
1) Perceive
2) Comprehend
3) Project
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
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.
RCO Use Case

- **Initial Conditions.** Aircraft is enroute. There is one Pilot On Board and a dispatcher flight following, both assisted by autonomy.
- **Step 1. Detection and Alerting of Thunderstorm.**
- **Step 2.** Dispatcher informs POB of cell.
- **Step 3.** Modification of Flight Plan.
- **Step 4.** Dispatch uplinks modified flight plan.
- **Step 5.** POB requests clearance for flight plan from ATC.
- **Step 6.** ATC rejects clearance.
- **Step 7.** Planning for Delay.
- **Step 8.** POB requests clearance from ATC.
- **Step 9.** POB tells Agent to implement the new clearance.

From Shively et al. (2016)
RCO Pattern

Supervisory Relationship

Cooperative Relationship

From Shively et al. (2016)
RCO Measures

Management Command

Aircraft

ATC

Dispatch
RCO Measures

Cooperation: Consider condition of other

Management: Distribute tasks

Situation Awareness: Monitoring other

Decision Making: Elicit options
RCO Measures

Decision Making
3) Select option
RCO Measures

Situation Awareness
3) Project

Decision Making
2) Generate options
Auto TCAS Use Case

• **Initial Conditions.** RCO with onboard Auto TCAS Agent

• **Step 1.** Agent detects traffic and provides avoidance option

• **Step 2.** POB does not react in time

• **Step 3.** Agent implements option
Auto TCAS Measures

Management
  Command

Situation Awareness
  Monitor

Cooperation:
  Consider condition of other

Decision Making:
  Elicit options

Situation Awareness
3) Project

Decision Making
3) Select option

Management
6) allows the human a restricted time to veto before automatic execution
Situation Awareness
3) Project

Decision Making
2) Generate options

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NASA UAS Ground Station
**UAS Evaluation**

**Management**
- Command
- Situation Awareness
- Monitor

**Situation Awareness**
3) Project

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

**Decision Making**
2) Generate options

UAS detects conflict and provides avoidance arc
Agent and Relationship Measures

**Agent**

**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
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3) Select option
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**Management (Sheridan)**
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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 behavioral markers to test performance
Next Steps

• Apply measures to more use cases
• Use measures to drive improvements to NASA autonomy projects
QUESTIONS?
Cooperation

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

• The term behavioral markers refers to a prescribed set of behaviors indicative of some aspect of performance (Flin & Martin, 2001)
**RCO Use Case**

- **Initial Conditions.** FLYSKY12 is en route from SFO to ORD. There is one POB and a dispatcher flight following.

- **Step 1. Detection and Alerting of Thunderstorm.** Dispatch automation informs dispatcher of convective cell growing on flight path of FLYSKY12.

- **Step 2. Dispatcher informs POB of cell. Step 3. Modification of Flight Plan.** Seeing a need to re-route, the dispatcher requests modified flight plan from dispatch automation. Dispatch automation returns modified flight plan.

- **Step 4. Dispatch uplinks modified flight plan.**

- **Step 5. POB requests clearance for flight plan from ATC.**

- **Step 6. ATC rejects clearance.** ATC tells POB that aircraft must take additional six-minute delay for new arrival slot coming into ORD.

- **Step 7. Planning for Delay.** POB asks automation for alternatives to take six-minute delay. Automation provides two alternatives: a) Slow down, saves fuel but risks further movement/growth of cell b) Hold past cell, more fuel burn but lower risk of further deviations.

- **Step 8. POB requests clearance from ATC.** Modified with holding after passing cell; ATC approves request.

- **Step 9. POB tells Agent to implement the new clearance.** Agent sets autopilot in accord with