A Human-Autonomy Teaming Approach for a Flight-Following Task

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Problems with Automation

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- Incidents and accidents result from pilots failing to understand increasingly sophisticated aircraft systems
  - These systems are often **brittle** and rarely degrade gracefully
  - Automation helps when all goes well but leaves the human **out-of-the-loop** when it fails
  - Automation interfaces often lack **transparency**, not facilitating understanding or tracking of the system
  - Disuse and misuse of automation (**miscalibrated trust**) have lead to real-world mishaps and tragedies

- Human involvement with increasingly sophisticated automated systems must adjust to allow for a more dynamic relationship involving cooperation and teamwork

Purpose

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- Part-task study to demonstrate, evaluate and refine proposed tenets of human-autonomy teaming (HAT)
  - Bi-directional communication
  - Transparency
  - Operator-directed interface

- Built on an earlier ground station to minimize development and focused primarily on interactions with one piece of software

- Overall goal is to develop a framework for HAT in aviation and provide guidelines and recommendations for its application

HAT Simulation: Tasks

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- Participants: 4 Dispatchers, 2 Pilots
- Participants, with the help of automation, monitored aircraft
  - Alerted pilots when
    - Aircraft was off path or pilot failed to comply with clearances
    - Significant weather events affect aircraft trajectory
    - Pilot failed to act on EICAS alerts
  - Rerouted aircraft when
    - Weather impacted the route
    - System failures or medical events force diversions
- Ran two ~50-min scenarios, containing approximately 40 aircraft and 6 off-nominal events
  - One scenario with HAT tools, one scenario without HAT tools

Autonomous Constrainted Flight Planner

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ELP: Emergency Landing Planner (2007-2012)

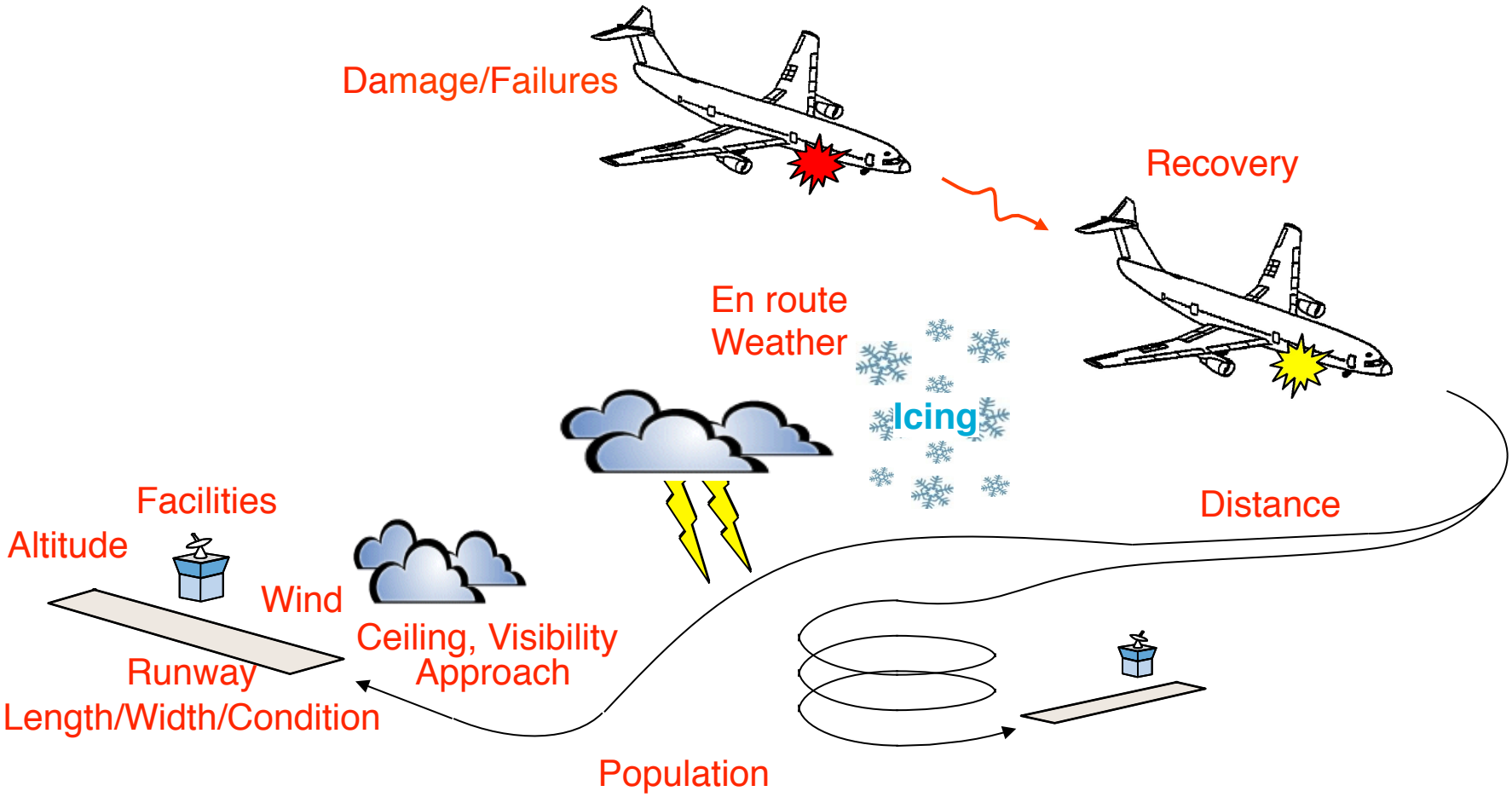
- Cockpit decision aid
- Route planning for (serious) emergencies
  - control system failures
  - physical damage
  - fires
- Time & safety were dominant considerations

ACFP: Autonomous Constrained Flight Planer (2013-2017)

- Ground station decision aid
- Diversion selection, route planning, route evaluation
  - weather diversion
  - medical emergencies
  - less critical system failures

Meuleau, N., Plaunt, C., Smith, D.E., Smith T.B.: An Emergency Landing Planner for Damaged Aircraft. In: Proceedings of the Twenty-First Innovative Application of Artificial Intelligence Conference, pp. 114--121 (2009)

ELP Objective



Find the best landing sites and routes for the aircraft

Emergency Page on the CDU

Runway length

Runway

Airport

Select

Principal Risks

Page #

Distance to airport

Bearing to airport

Show Airport Info Page

Update

Execute the selection

Go to Previous/Next Page

Simulated Ground Station

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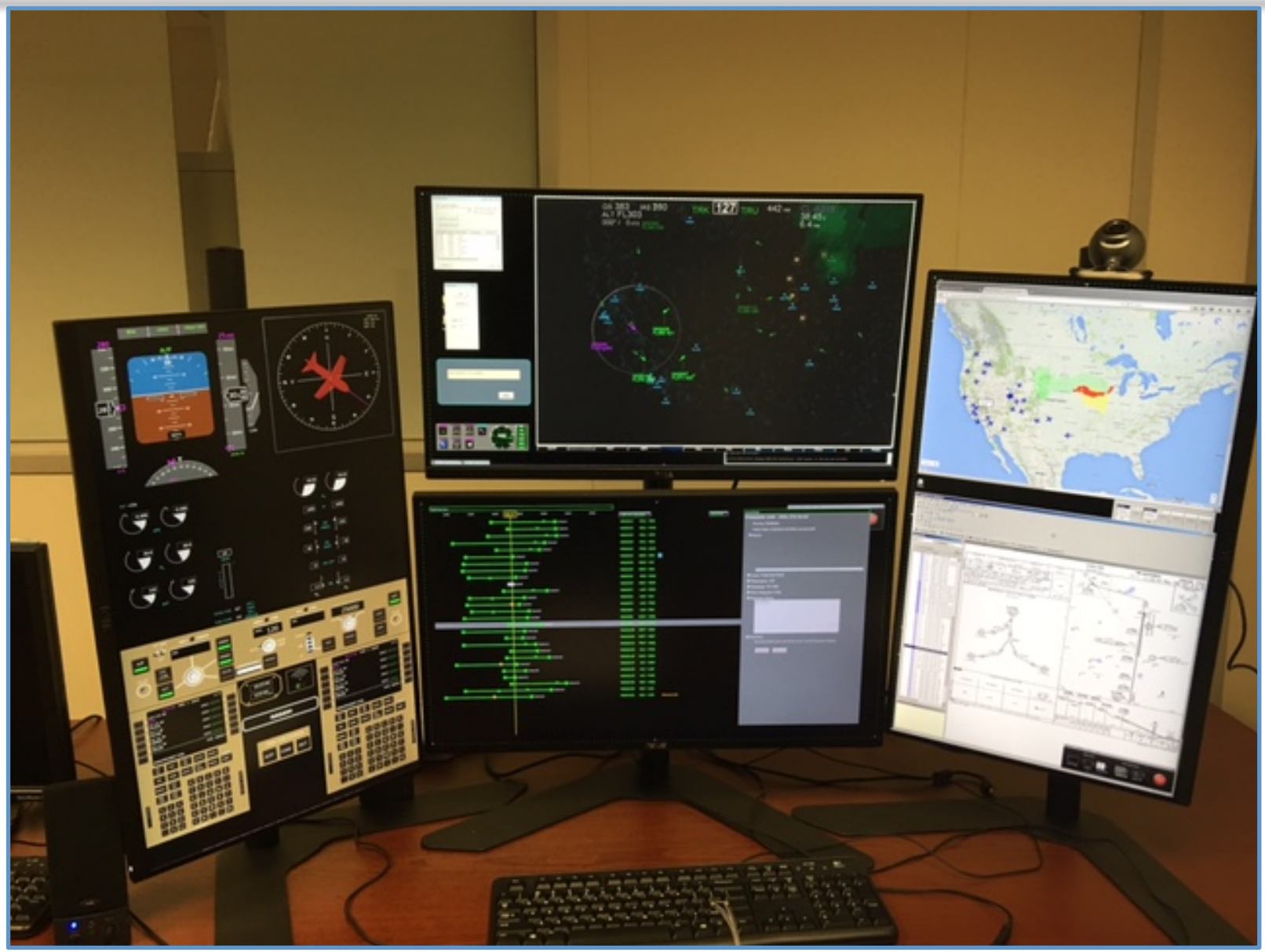

Building in HAT Tenets to the Ground Station

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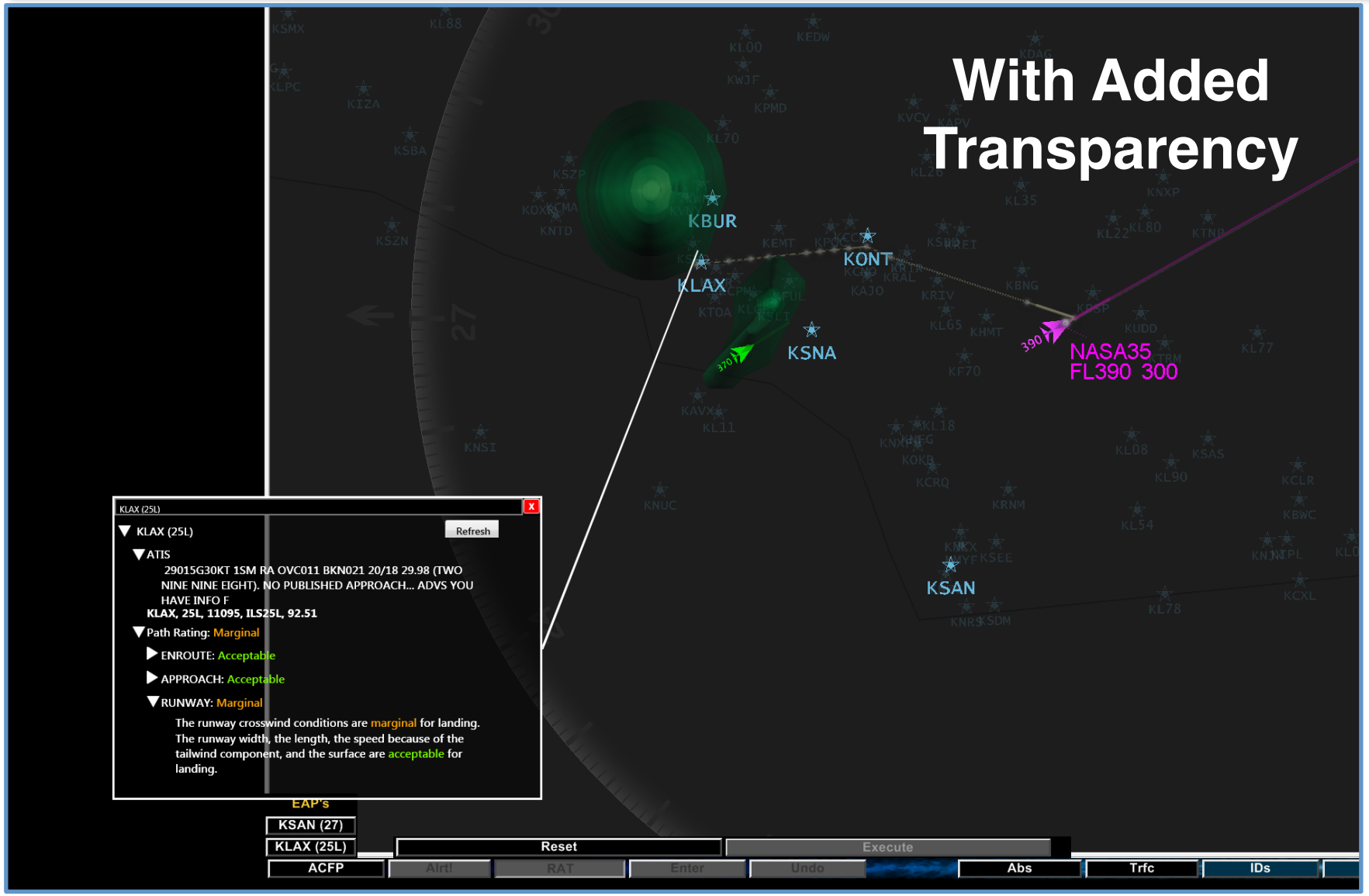

Building in HAT Tenets to the Ground Station

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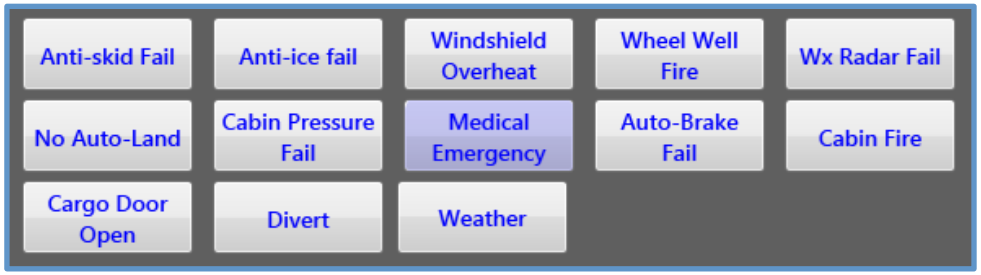
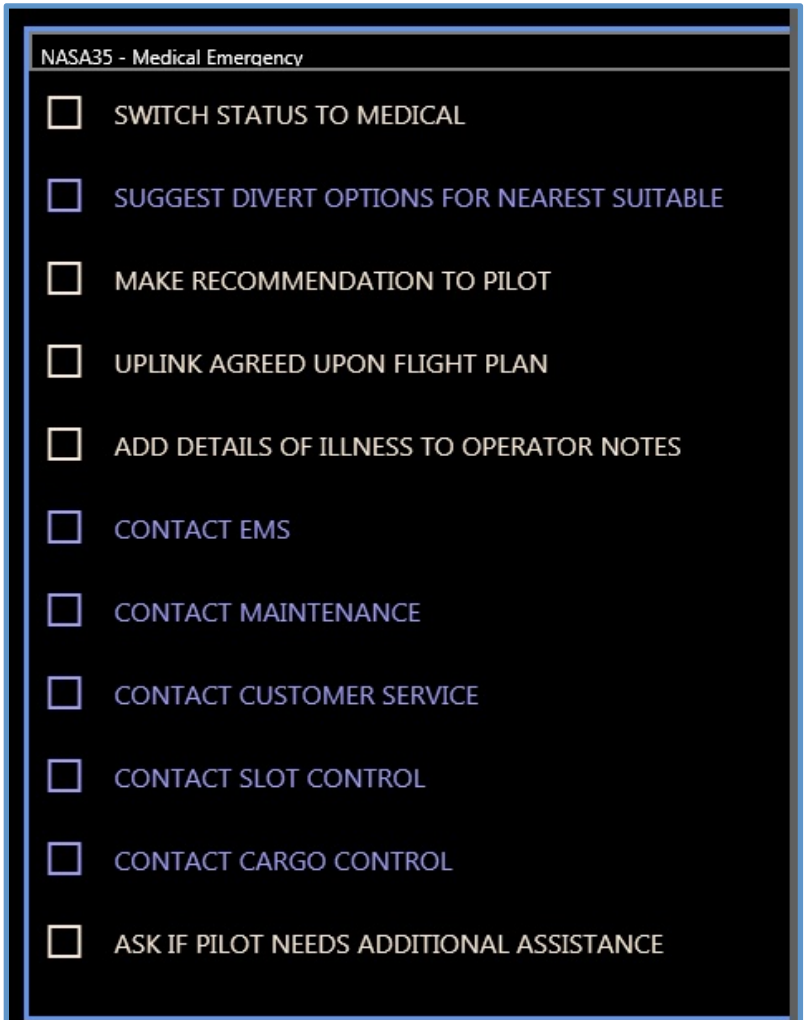
- Human-Directed
  - Operator calls “Plays” to determine who does what





- A play encapsulates a plan for achieving a goal. It includes roles and responsibilities
  - what is the automation going to do
  - what is the operator going to do

Building in HAT Tenets to the Ground Station

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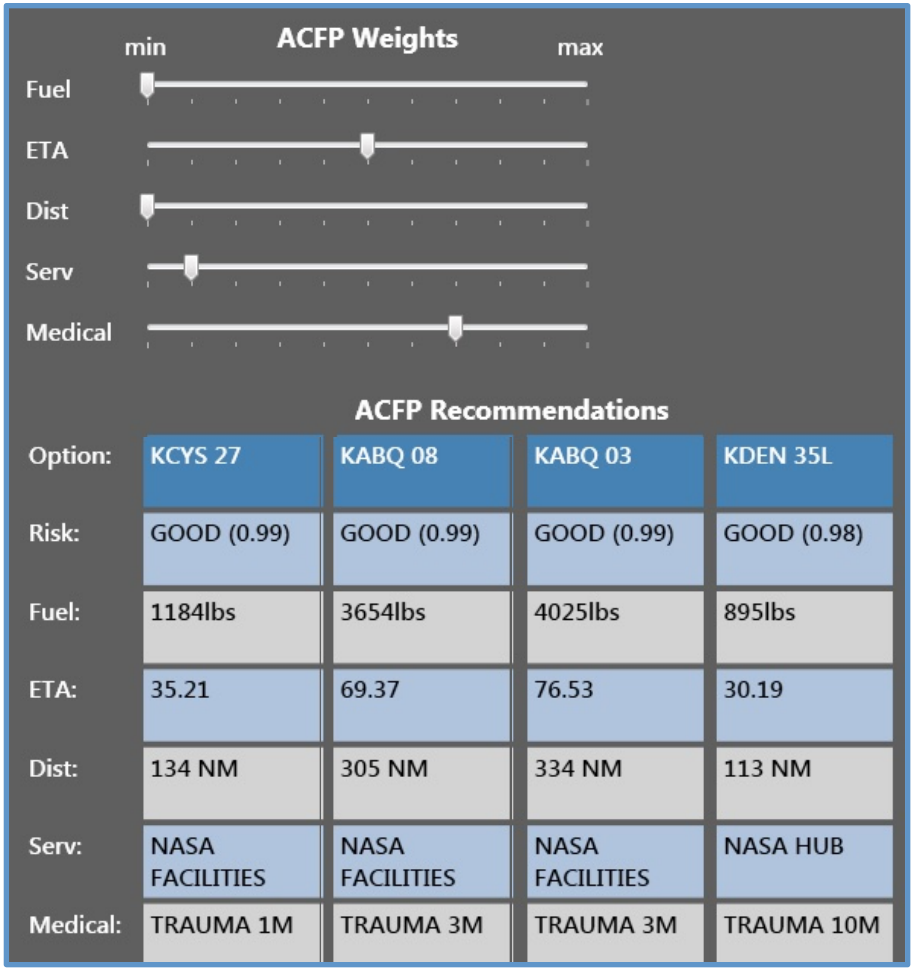
- Transparency
  - Divert reasoning and factor weights are displayed
  - Numeric output from ACFP was found to be misleading by pilots. Display now uses English categorical descriptions.
- Bi-directional Communication
  - Operators can change factor weights to match their priorities



ACFP Recommendations

Option:	KCYS 27	KABQ 08	KABQ 03	KDEN 35L
Risk:	GOOD (0.99)	GOOD (0.99)	GOOD (0.99)	GOOD (0.98)
Fuel:	1184lbs	3654lbs	4025lbs	895lbs
ETA:	35.21	69.37	76.53	30.19
Dist:	134 NM	305 NM	334 NM	113 NM
Serv:	NASA FACILITIES	NASA FACILITIES	NASA FACILITIES	NASA HUB
Medical:	TRAUMA 1M	TRAUMA 3M	TRAUMA 3M	TRAUMA 10M

HAT Simulation: Results

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- Participants preferred the HAT condition overall ($M = 8.5$, $SD = 0.55$)

- HAT displays were preferred with regard to:
  - keeping up with operationally important issues ($M = 8.67$, $SD = 0.52$)
  - ensuring the necessary situation awareness for the task ($M = 8.67$, $SD = 0.52$)
  - integrating information from a variety of sources ($M = 8.67$, $SD = 0.52$)
  - reducing workload necessary for the task ($M = 8.33$, SD = 0.82)
  - efficiency ($M = 8.33$, $SD = 0.82$)

- Participants reported greater confidence that their diversion choice was appropriate in the HAT condition ($M = 7.83$, $SD = 1.47$) compared to the No HAT condition ($M = 6.33$, $SD = 2.07$; $t(5) = 4.39$, $p = .01$)

- ACFP was rated as useful ($M = 5.83$, $SD = 0.82$), particularly during emergency situations
  - *"Everything is easy and accessible in emergency situations. No need to consult many other programs to get various info."*

HAT Simulation: Results

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- Supporting Bi-directional Communication
  - ACFP weights
    - improved automation's ability to handle unusual situations ($M = 7.83$, $SD = 1.60$)
    - were useful in making divert decisions ($M = 8.33$, $SD = 0.82$)
    - were liked ($M = 8.33$, $SD = 1.21$)
    - *"[the display] gave me the ability to see why, gave me control to change weights in variable(s)"*
- Building in Transparency
  - ACFP table
    - was helpful in making divert decisions ($M = 7.67$, $SD = 1.51$)
    - was liked ($M = 8.33$, $SD = 1.03$)
    - *"This [table] is wonderful…You would not find a dispatcher who would just be comfortable with making a decision without knowing why."*
- Creating an Operator Directed Interface with Plays
  - Electronic checklist
    - was liked ($M = 8.67$, $SD = 0.52$)
    - *"This electronic checklist was easier because it was right there on the screen and it eliminated a couple of steps"*

HAT Simulation: Summary

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- Participants liked where we were headed with the HAT concept
  - Increased Situation Awareness
  - Reduced Subjective Workload

- Things we didn't get quite right
  - Participants didn't always understand what the goal of a play was
  - Annunciations: People liked them but thought there were to many
  - Voice Control: Did not work well. Need a more complete grammar, better recognition

- Things we didn't get to
  - Airlines hate diverts. We need to put in support to help avoid them
  - Plays need more structure (branching logic)
  - Roles and responsibilities need to be more flexible
  - Limited ability to suggest alternatives

Where next?

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- Running another part-task study with HAT features implemented on the flight deck

- Developing a software framework for creating HAT Agents