Reduced Crew Operations Research

at NASA Ames Research Center
Initial RCO/SPO Efforts

• Motivation
  – Enable commercial transports to fly with only one pilot to save money and address a potential pilot shortage

• Possible Approaches to RCO/SPO
  – Support from flight deck automation
  – Remote support from a human operated ground station
  – Remote support from a human operated ground station and flight deck automation

• Goals and Objectives
  – Develop and evaluate advanced flight deck- and ground-based technologies and concepts utilizing
    • Unmanned Aircraft Systems (UAS) technologies
    • New air-ground datalink capabilities
    • Intelligent agents located on flight decks and at ground stations
Milestones

• SPO TIM- Spring 2012
  – Technical Interchange Meeting
  – Gain insight from members of aviation community regarding SPO

• Non Co-Located Pilot Simulation– Fall 2012
  – Tested the effects of separation on crew interaction
  – Low fidelity

• Air/Ground Simulation Evaluation– Fall 2013
  – Initial prototype ground station
  – Test new tools to mitigate issues found in SPO I
  – High fidelity flight deck/malfunctions

• Ground ConOps Simulation Evaluation – Summer 2014
  – Ground station interacts with multiple aircraft

• Multi-Aircraft Support Demonstration– Winter 2016
  – Ground station for multi-aircraft monitoring and support

• Human-Autonomy Teaming Demonstration – Summer 2016
  – Integration of human-autonomy teaming tools
SPO TIM

• Single Pilot Operations Technical Interchange Meeting
  – Primary focus to consider how tasks and responsibilities might be re-allocated to allow for SPO
  – Approximately 70 people attended who represented government, academia, industry
SPO TIM Findings

• Attendees seemed to believe that an exploration of SPO feasibility would be beneficial regardless of whether or not SPO is adopted
  – *Almost all components of current day NAS could reap benefits from SPO R&D*

• Most seemed to believe that SPO is feasible

• Generally believe biggest motivator for exploring SPO is the potential cost savings
  – *Mixed on whether SPO would actually result in cost savings*

• Identified issues, recommendations, and suggestions for research directions

Non Co-located Pilot Simulation

- Identified the impact of separation on crew interaction and decision-making
  - Lack of crew acknowledgements
  - Lack of Situation Awareness (SA) related to the other pilot, information gathering and decision making

Together Condition

Separate Condition
Concept of Operations
Ground Operators

• Ground operators collectively perform three core functions:
  1. *Conventional dispatch of multiple aircraft*
  2. *Distributed piloting support of multiple nominal aircraft*
  3. *Dedicated piloting support of a single off-nominal aircraft*

• Many possible structures for organizing ground operators to perform these core functions; some examples are:
  – *Hybrid ground operators* who perform functions 1, 2, and 3
  – *Specialist ground operators*, consisting of:
    • *Ground associates* who perform functions 1 and 2
    • *Ground pilots* who perform function 3
Ground Operators

Org. Structure

- Hybrid Ground Operators
  - Supervisor
  - Hybrid Ground Operator Unit

- Conventional dispatch of multiple aircraft
- Distributed piloting support of multiple nominal aircraft
- Dedicated piloting support of one off-nominal aircraft

- Ground Associates
- Specialist Ground Operator Unit
- Ground Pilots
Concept of Operations
Development Plan

• Objectives
  – Define functions for flight deck and ground station operators
  – Develop new tools for flight deck and ground station
  – Develop new procedures for flight deck/ground station interaction

• Approach
  – Spiral development
    • Start with things as close to current day as possible and change incrementally
  – Focus on Crew Resource Management (CRM)
    • If the ground operator can interact with the aircraft and onboard pilot as effectively as a first officer does today, we know we can achieve safety goals
Air/Ground Simulation Evaluation

- Developed prototype ground station and collaboration tools
- Identified issues with ground pilot’s ability to assist multiple aircraft simultaneously

Collaborative Tools: Flight Deck

Collaborative Tools: Ground Station
Ground ConOps Simulation Evaluation

- Examined handoffs between Ground Operator and Remote Pilot
- No situation awareness issues found
Multi-aircraft Support Demonstration

- Developed ground station for multi-aircraft monitoring and support
Moving toward Human-Autonomy Teaming

Develop a framework for human-autonomy teaming in aviation and provide guidelines and recommendations for its application. The framework will identify critical aspects of human-autonomy teaming and provide a mechanism for evaluation.
What is HAT

• Human-Autonomy Teaming (HAT) is characterized by collaboration between the human and the autonomy, rather than just a decision support aid. They share goals, information and a common language.

• HAT extends CRM principles used between human operators to interactions between humans and automation resulting in cross validation of actions and situation awareness by both operators and automation.
HAT Principles

• Transparency
  – *Good CRM between humans requires team members to understand what the others are doing and why*

• Negotiation
  – *Good CRM between humans requires people with different information to enter a dialog about how best to achieve their goals*

• Shared Language/Communication
  – *Good CRM between humans requires an explicit communication about goals and actions*

• Human Directed
  – *We believe that the human should be giving explicit direction to the automation*
Autonomous Constrained Flight Planner (ACFP)

Recommended airports - rank ordered.
Adding HAT Principles to the Ground Station

With Added Transparency
Adding HAT Principles to the Ground Station

- **Transparency:** Divert reasoning and factor weights are displayed.

- **Negotiation/Dialog:** Operators can change factor weights to match their priorities.

- **Shared Language/Communication:** Numeric output from ACFP was found to be misleading by pilots. Display now uses English categorical descriptions.
Adding HAT Principles to the Ground Station

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

<table>
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<tr>
<th>Anti-skid Fail</th>
<th>Anti-ice fail</th>
<th>Windsheild Overheat</th>
<th>Wheel Well Fire</th>
<th>Wx Radar Fail</th>
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<tr>
<td>No Auto-Land</td>
<td>Cabin Pressure Fail</td>
<td>Medical Emergency</td>
<td>Auto-Brake Fail</td>
<td>Cabin Fire</td>
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<tr>
<td>Cargo Door Open</td>
<td>Divert</td>
<td>Weather</td>
<td></td>
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- NASA35 - Medical Emergency
  - SWITCH STATUS TO MEDICAL
  - SUGGEST DIVERT OPTIONS FOR NEAREST SUITABLE
  - MAKE RECOMMENDATION TO PILOT
  - UPLINK AGREED UPON FLIGHT PLAN
  - ADD DETAILS OF ILLNESS TO OPERATOR NOTES
  - CONTACT EMS
  - CONTACT MAINTENANCE
  - CONTACT CUSTOMER SERVICE
  - CONTACT SLOT CONTROL
  - CONTACT CARGO CONTROL
  - ASK IF PILOT NEEDS ADDITIONAL ASSISTANCE