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
    - *Jointly hosted by Ames and Langley at NASA Ames April 10-12, 2012*
    - *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

Comerford, D., Brandt, S. L., Lachter, J., Wu, S.-C., Mogford, R., Battiste, V., & Johnson, W. W. (2013). *NASA's single-pilot operations technical interchange meeting; Proceedings and findings.* (Report no. NASA-CP-2013-216513). Moffett Field, CA: NASA Ames Research Center.

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
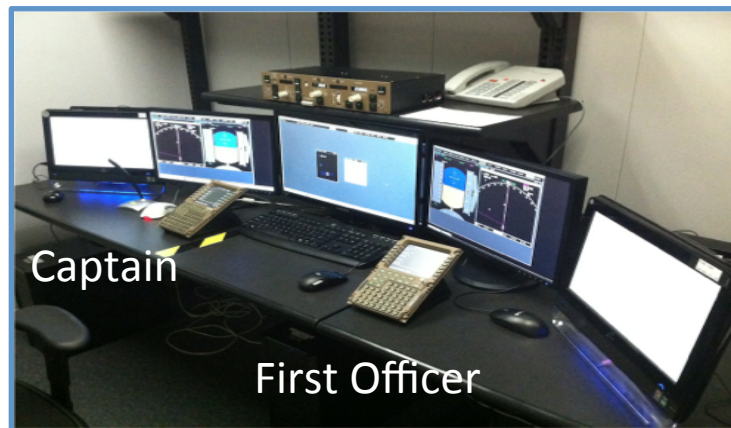
Separate Condition

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
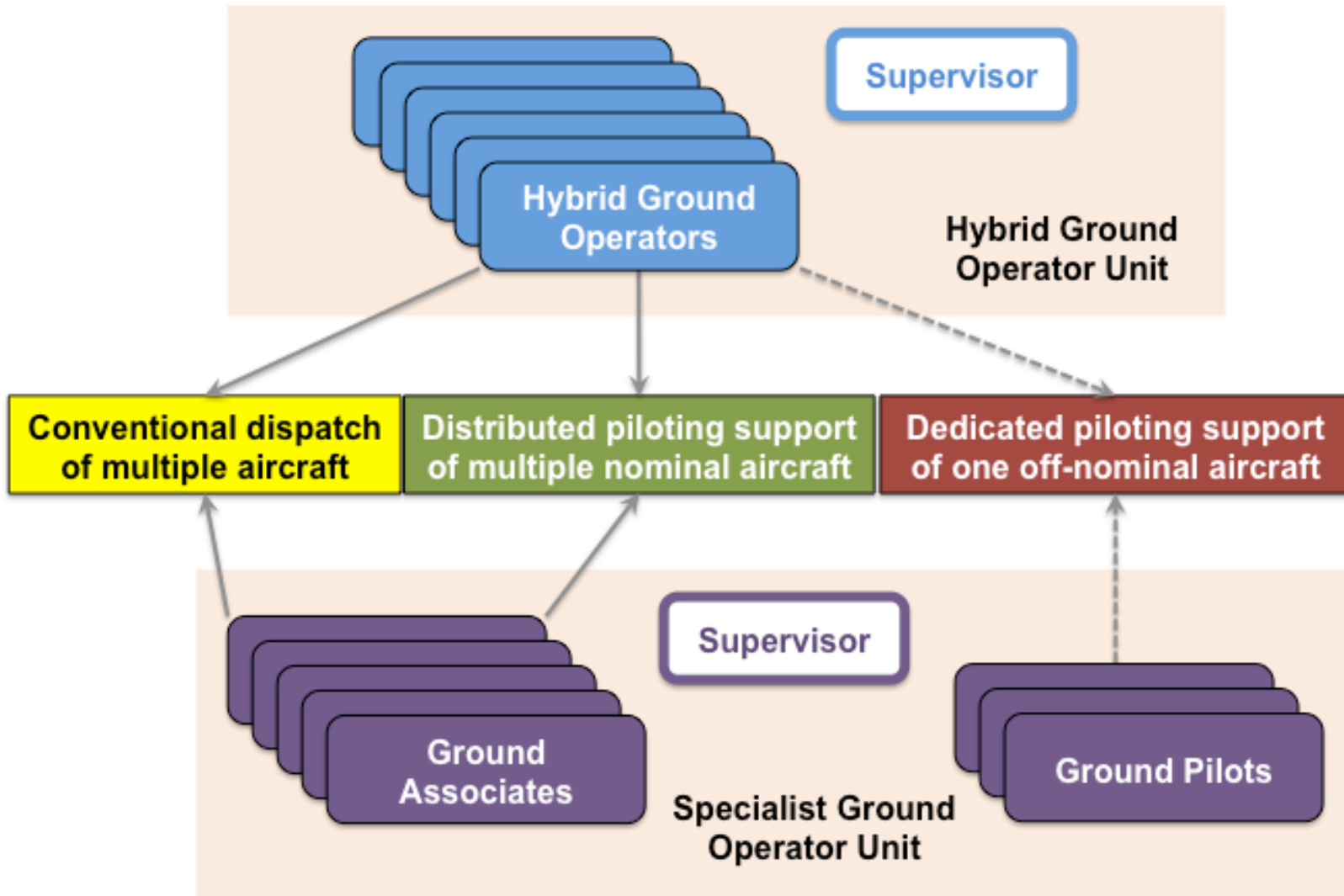
Concept of Operations
Development Plan

- 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*

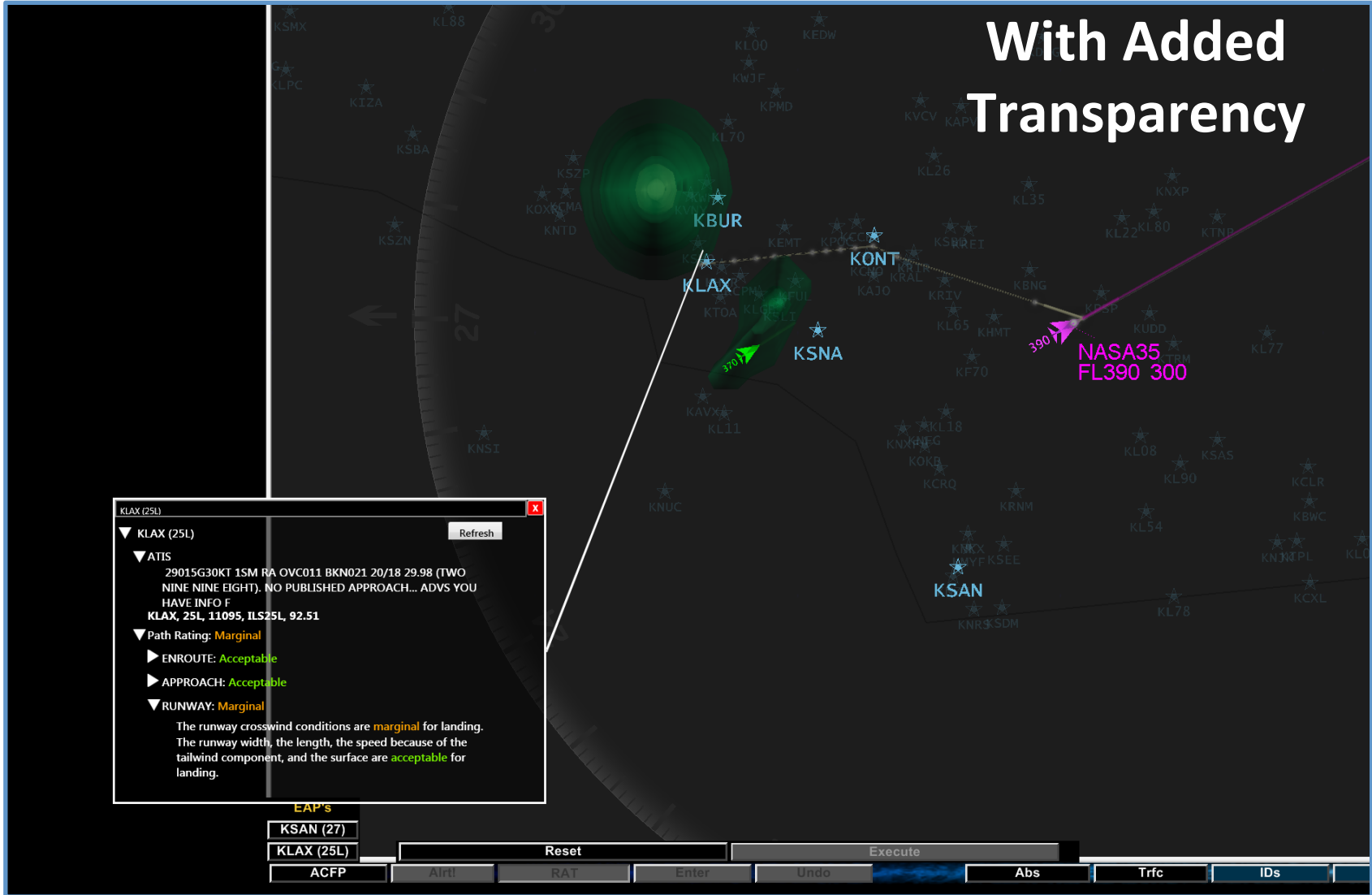# Autonomous Constrained Flight Planner (ACFP)
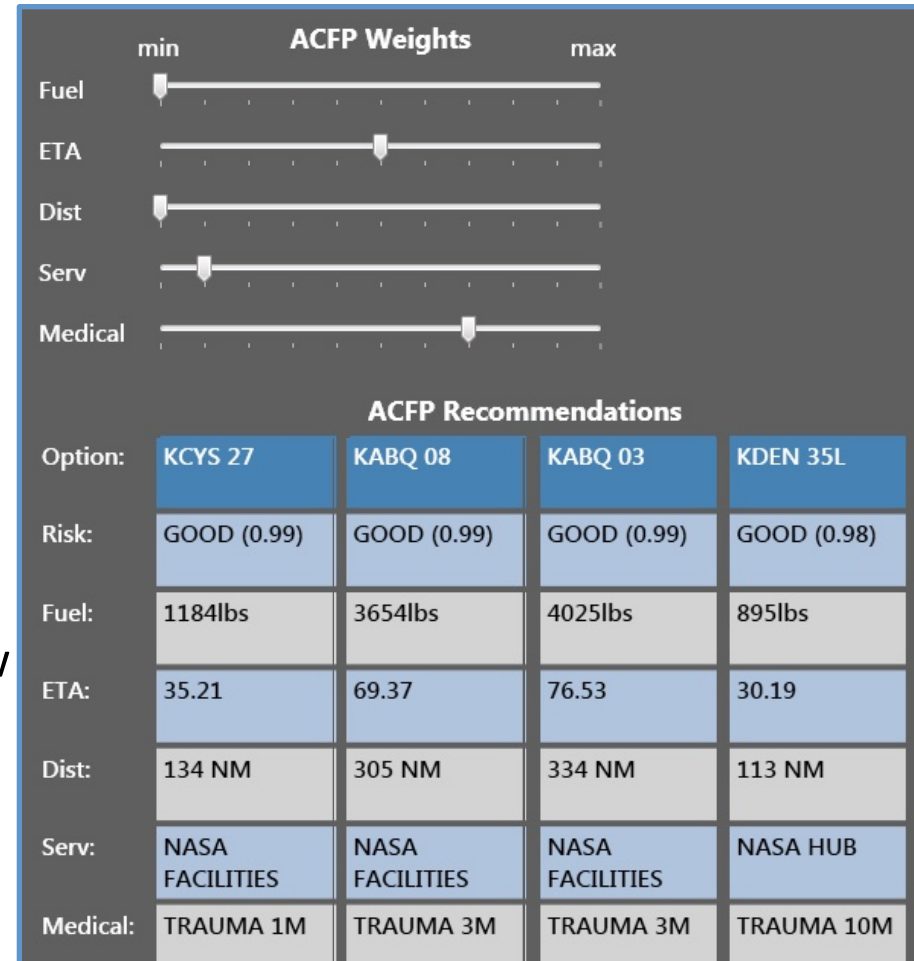

Recommended airports
- rank ordered.

Adding HAT Principles to the Ground Station

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.

ACFP Weights

	min		max
Fuel			
ETA			
Dist			
Serv			
Medical			

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

Adding HAT Principles to the Ground Station

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

Anti-skid Fail	Anti-ice fail	Windshield Overheat	Wheel Well Fire	Wx Radar Fail
No Auto-Land	Cabin Pressure Fail	Medical Emergency	Auto-Brake Fail	Cabin Fire
Cargo Door Open	Divert	Weather		

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