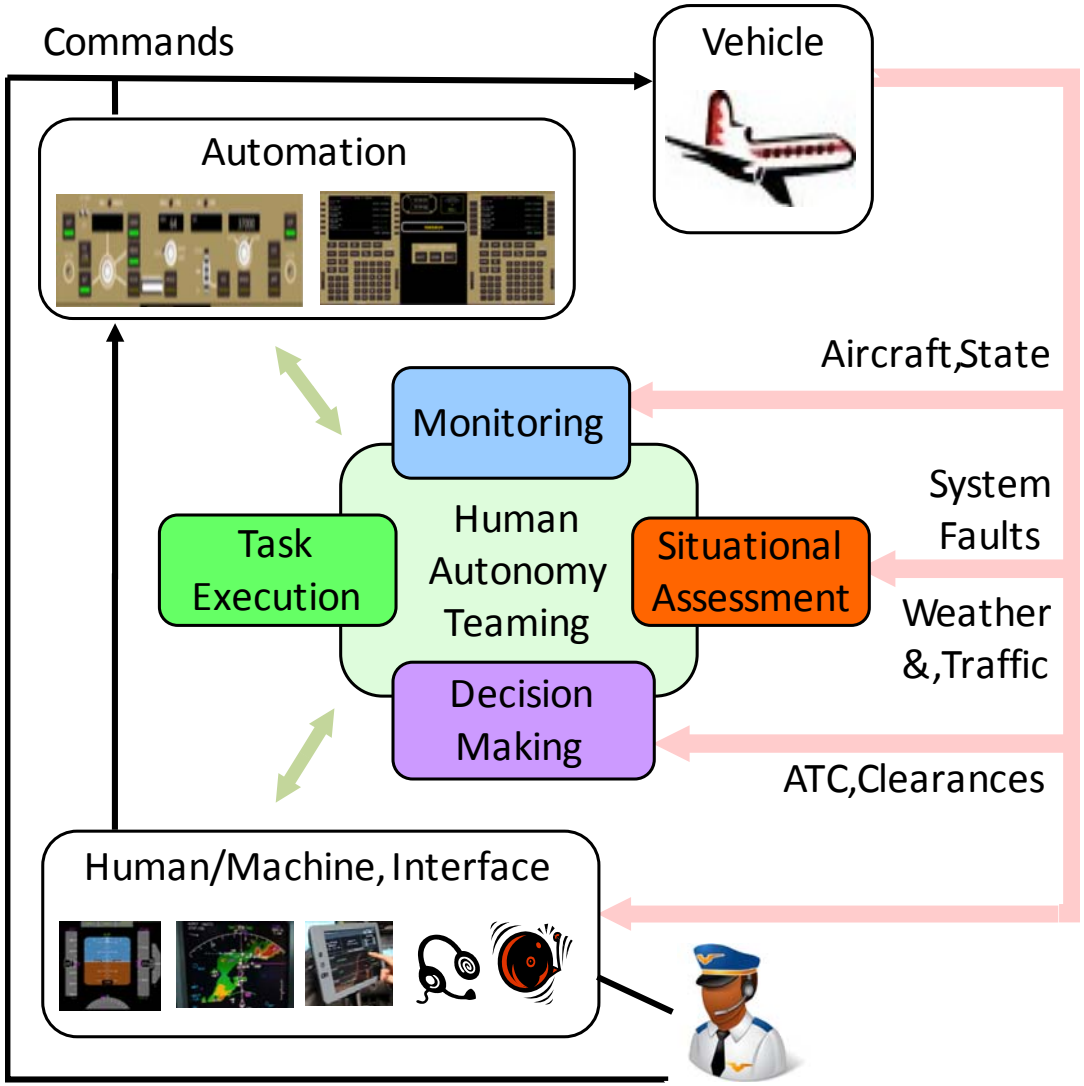
Understanding Human Autonomy Teaming Through Applications

Bimal Aponso, NASA Ames Research Center



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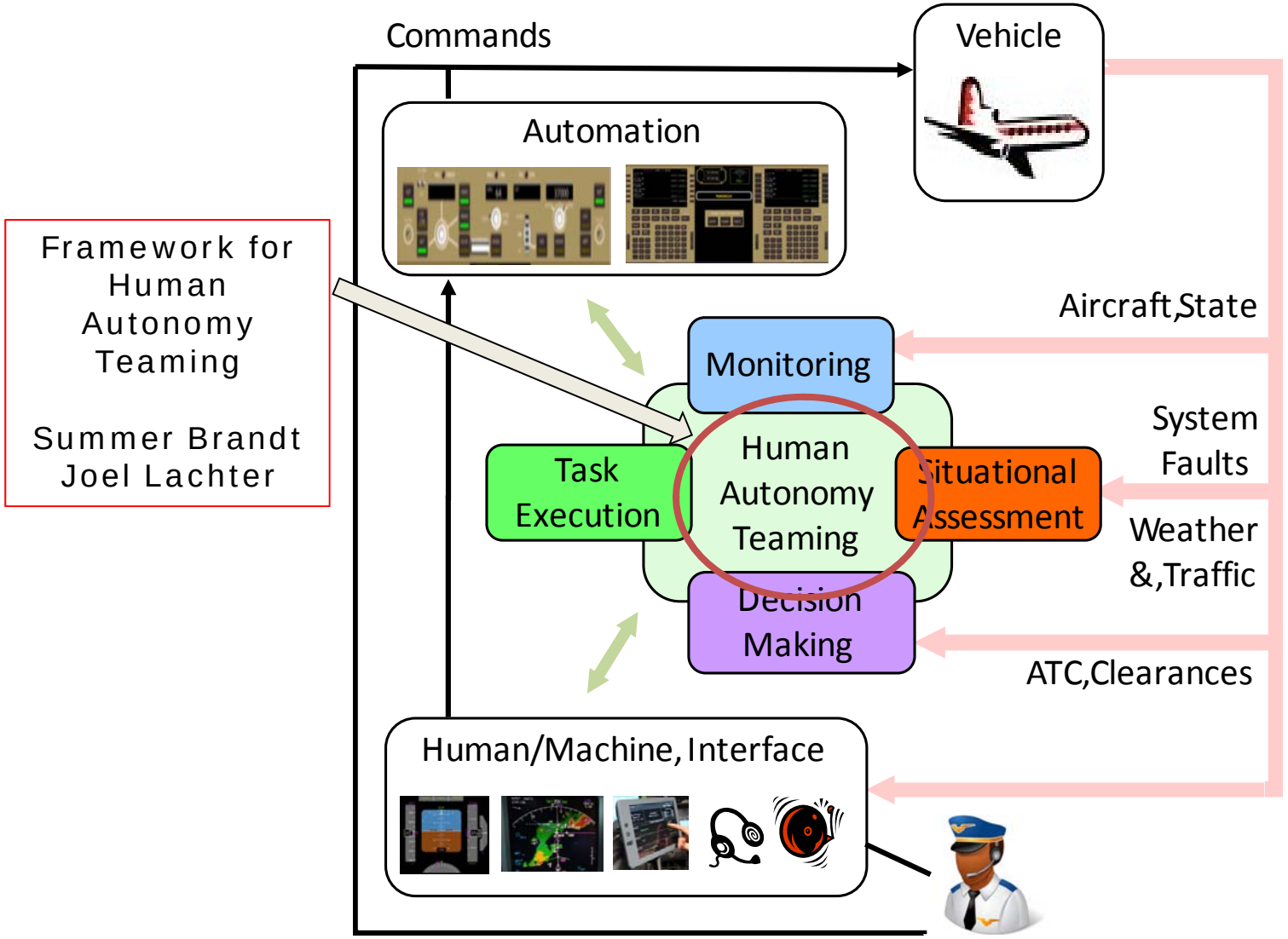

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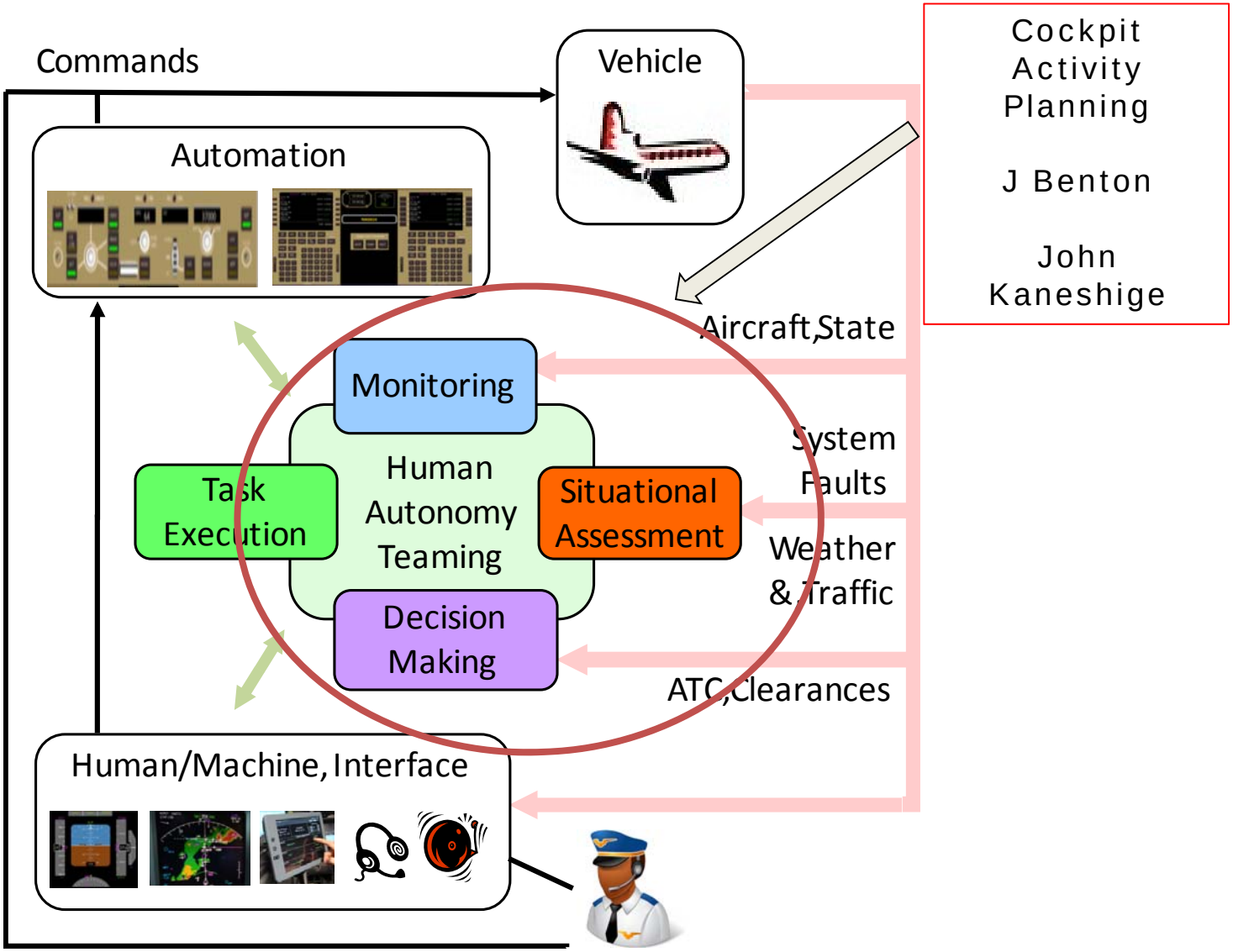

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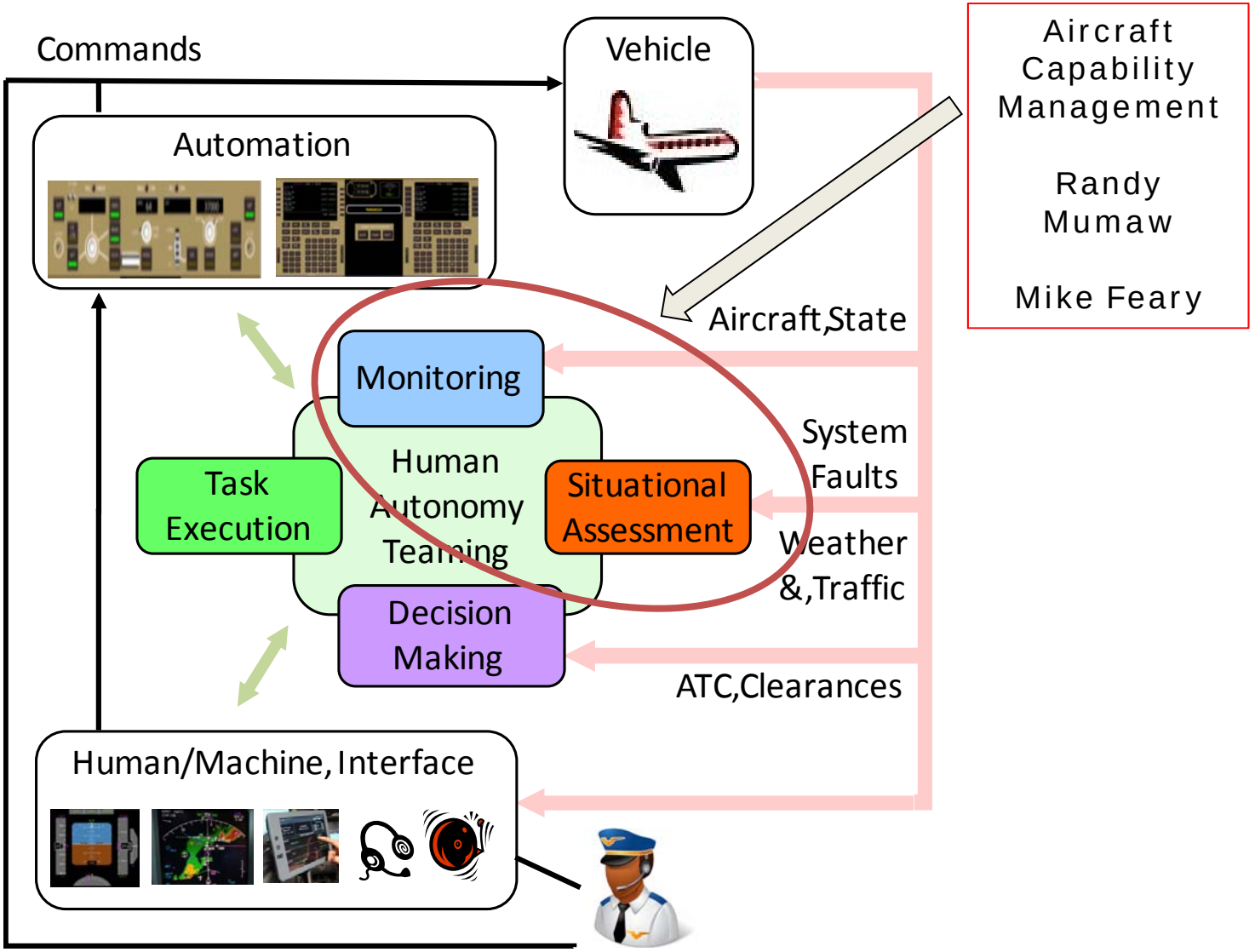
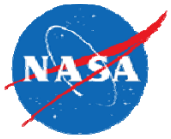




Human Autonomy Teaming

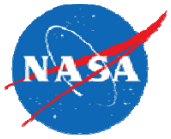
Summer Brandt
Joel Lachter
Jay Shively

February 16, 2017

Problems with Automation

- Brittle
  - Automation often operates well for a range of situations but requires human intervention to handle boundary conditions (Woods & Cook, 2006)
- Opaque
  - Automation interfaces often do not facilitate understanding or tracking of the system (Lyons, 2013)
- Miscalibrated Trust
  - Disuse and misuse of automation have lead to real-world mishaps and tragedies (Lee & See, 2004; Lyons & Stokes, 2012)
- Out–of-the-Loop Loss of Situation Awareness
  - Trade-off: automation helps manual performance and workload but recovering from automation failure is often worse (Endsley, 2016; Onnasch, Wickens, Li, Manzey, 2014)

HAT Solutions to Problems with Automation



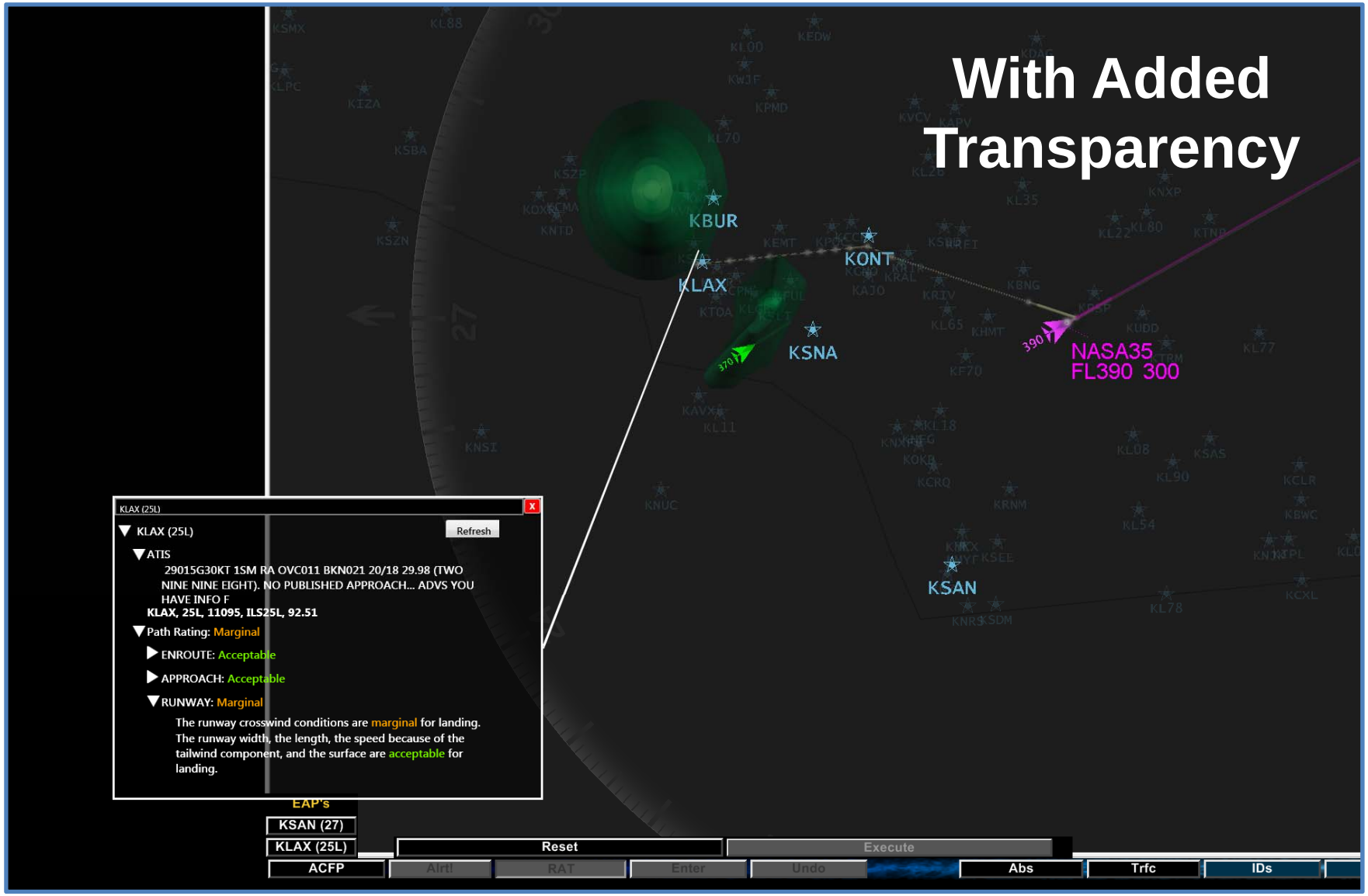
- Brittle
  - **Negotiated decisions** puts a layer of human flexibility into system behavior
- Opaque
  - Requires that systems be designed to be **transparent**, present **rationale** and confidence
  - Communication should be in terms the operator can easily understand (**shared language**)
- Miscalibrated Trust
  - Automation **display of rationale** helps human operator know when to trust it
- Out–of-the-Loop Loss of Situation Awareness
  - Keep **operator in control**; adaptable, not adaptive automation
  - Greater interaction (e.g., **negotiation**) with automation reduces likelihood of being out of the loop

Simulated Ground Station

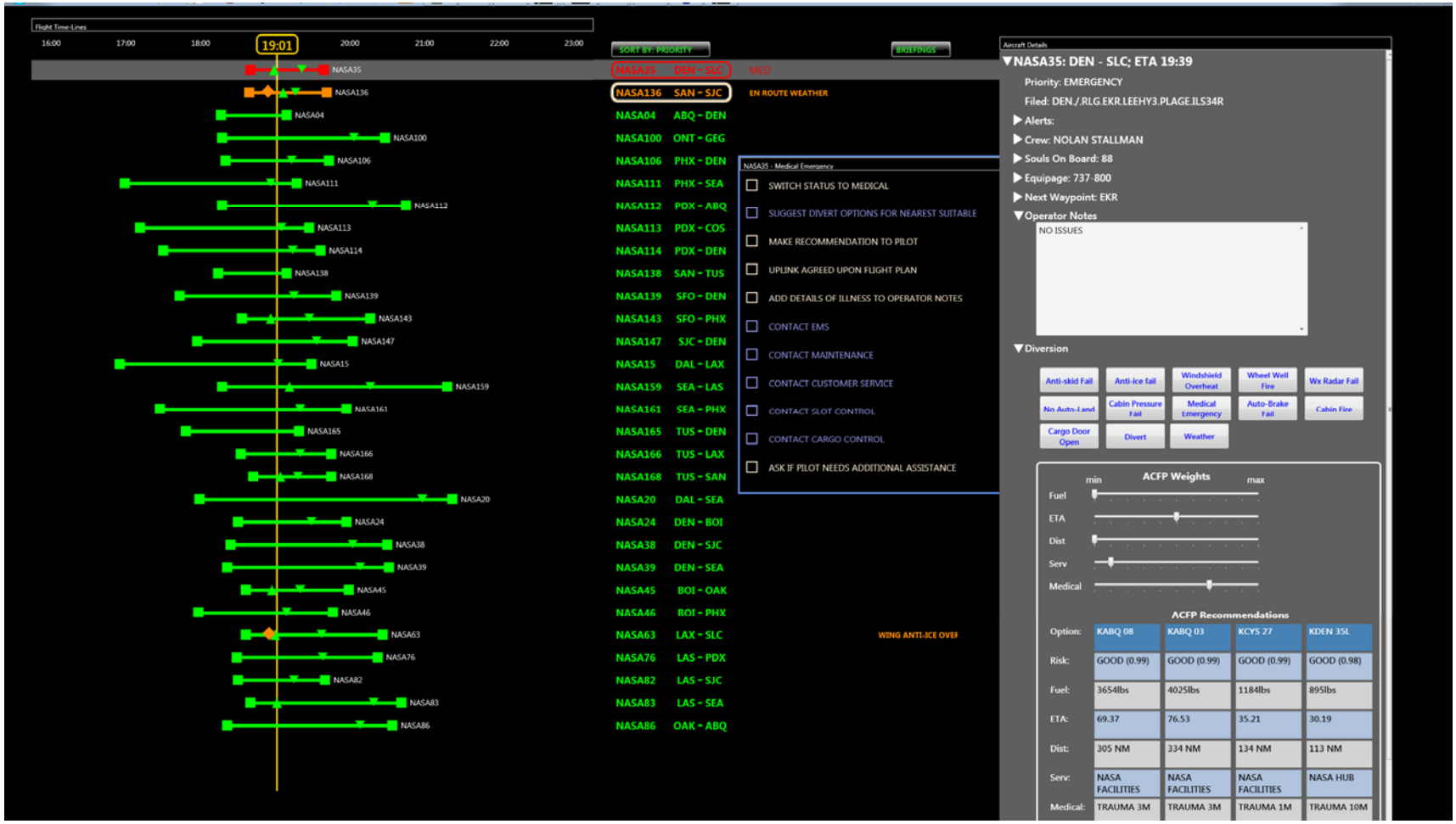
Autonomous Constrained Flight Planner (ACFP)

Recommended airports - rank ordered.

Adding HAT Principles to the Ground Station

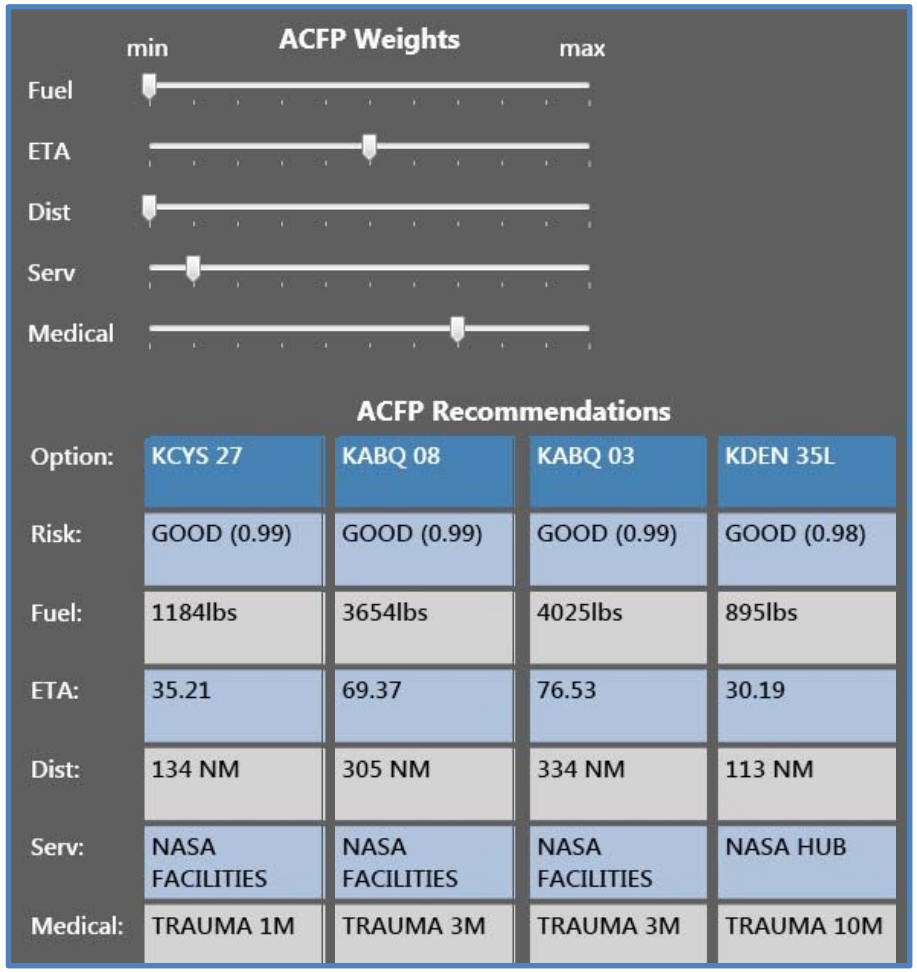


Adding HAT Principles to the Ground Station



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.

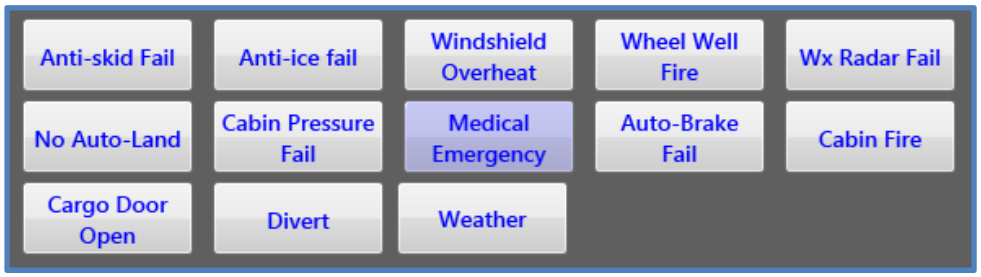


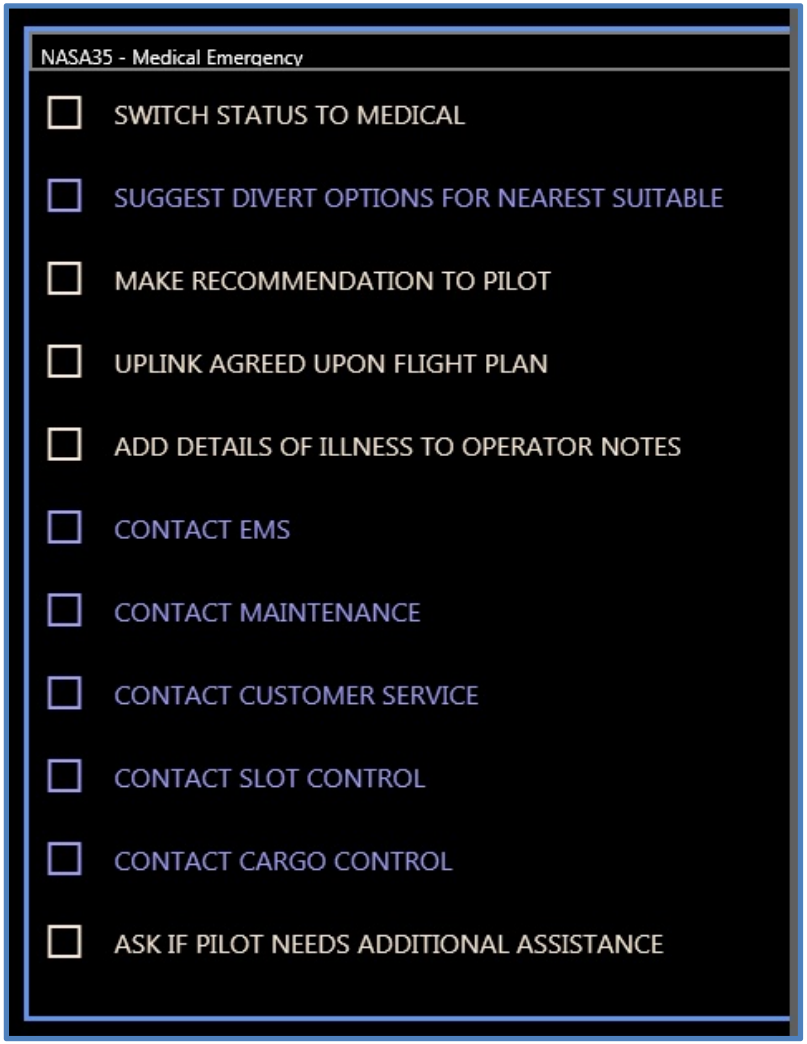
ACFP Recommendations

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





HAT Simulation: Tasks

- Participants, with the help of automation, monitored 30 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

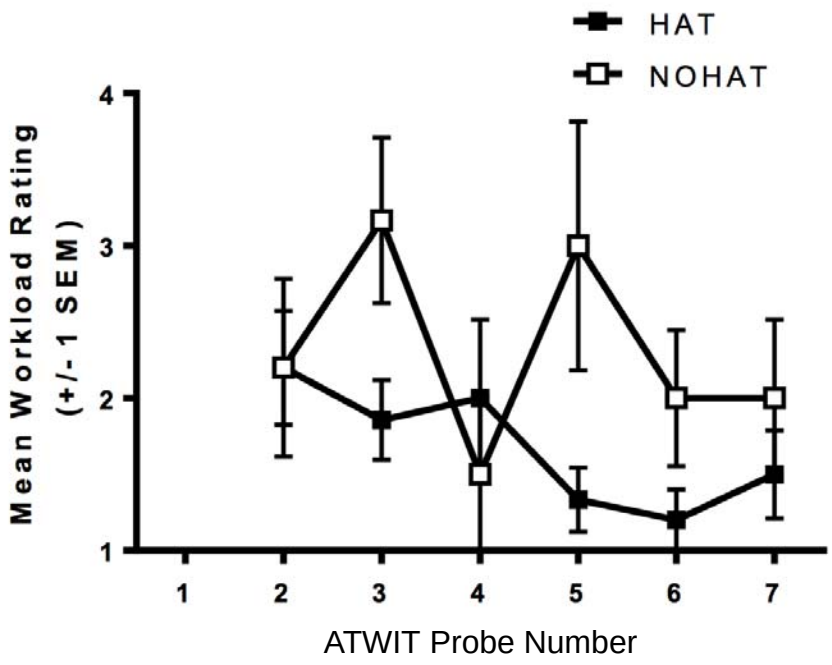
- Ran with HAT tools and without HAT tools

HAT Simulation: Results

- Participants preferred the HAT condition overall (rated 8.5 out of 9).
- HAT displays and automation preferred for keeping up with operationally important issues (rated 8.67 out of 9)
- HAT displays and automation provided enough situational awareness to complete the task (rated 8.67 out of 9)
- HAT displays and automation reduced the workload relative to no HAT (rated 8.33 out of 9)

HAT Simulation: Results

- HAT workload reduction was marginally significant (HAT mean 1.7; No HAT mean 2.3, p = .07)



HAT Simulation: Debrief

- Transparency/Shared Language
  - "This [the recommendations table] is wonderful…. You would not find a dispatcher who would just be comfortable with making a decision without knowing why."
- Negotiation
  - "The sliders was [sic] awesome, especially because you can customize the route…. I am able to see what the difference was between my decision and [the computer's decision]."
- Human-Directed Plays
  - "This one was definitely awesome. Sometimes [without HAT] I even took my own decisions and forgot to look at the QRH because I was very busy, but that didn't happen when I had the HAT."

Where we are and planned FY17 work

- Trust repair with automated system part-task

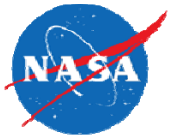
Now (Transparency Part Task)

- Implementing HAT features on the flight deck

Spring ’17 (Flight Deck)

- Developing a software framework for creating HAT Agents
- Updating ground station re-routing tool
- UX testing

Summer ’17 (Ground Station Agent)

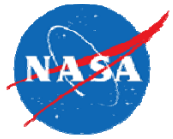


Cockpit Hierarchical Activity Planning and Execution

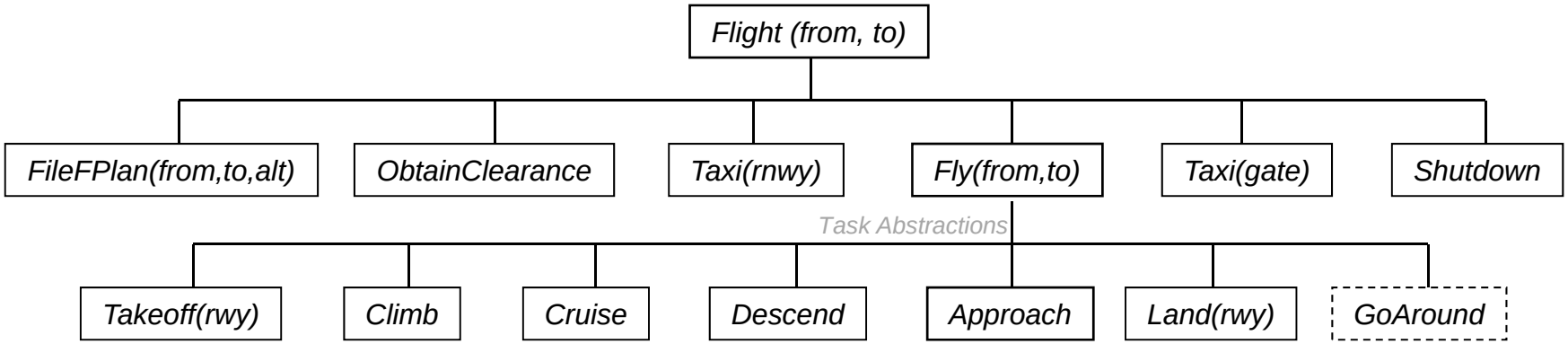
J Benton
John Kaneshige

February 16, 2017

Hierarchical Activity Planning

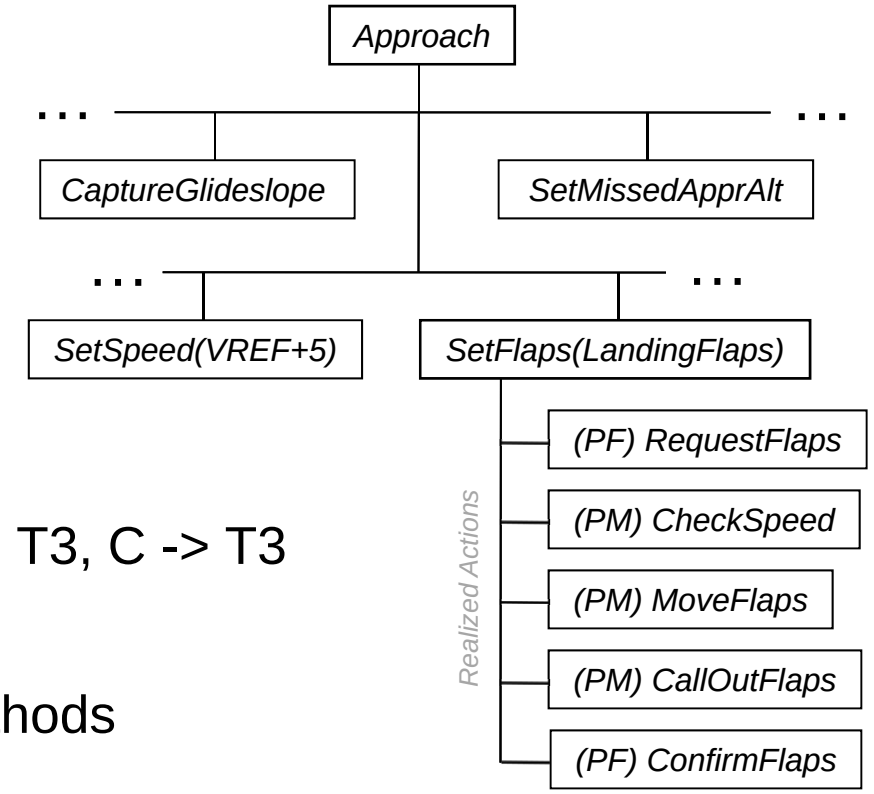


- Abstract idea of what will happen next
  - Abstract plans, not fully defined (instantiated) at start
- Partially ordered, conditions on tasks
  - Some tasks can be completed in any order
  - Timing is dependent on circumstances
- Precise tasks become more clear as time goes on
  - Interleaved execution and expansion
  - Clearance changes, weather, equipment failures, errors cause plan revision
  - Monitoring/projection detects failures, triggers revision

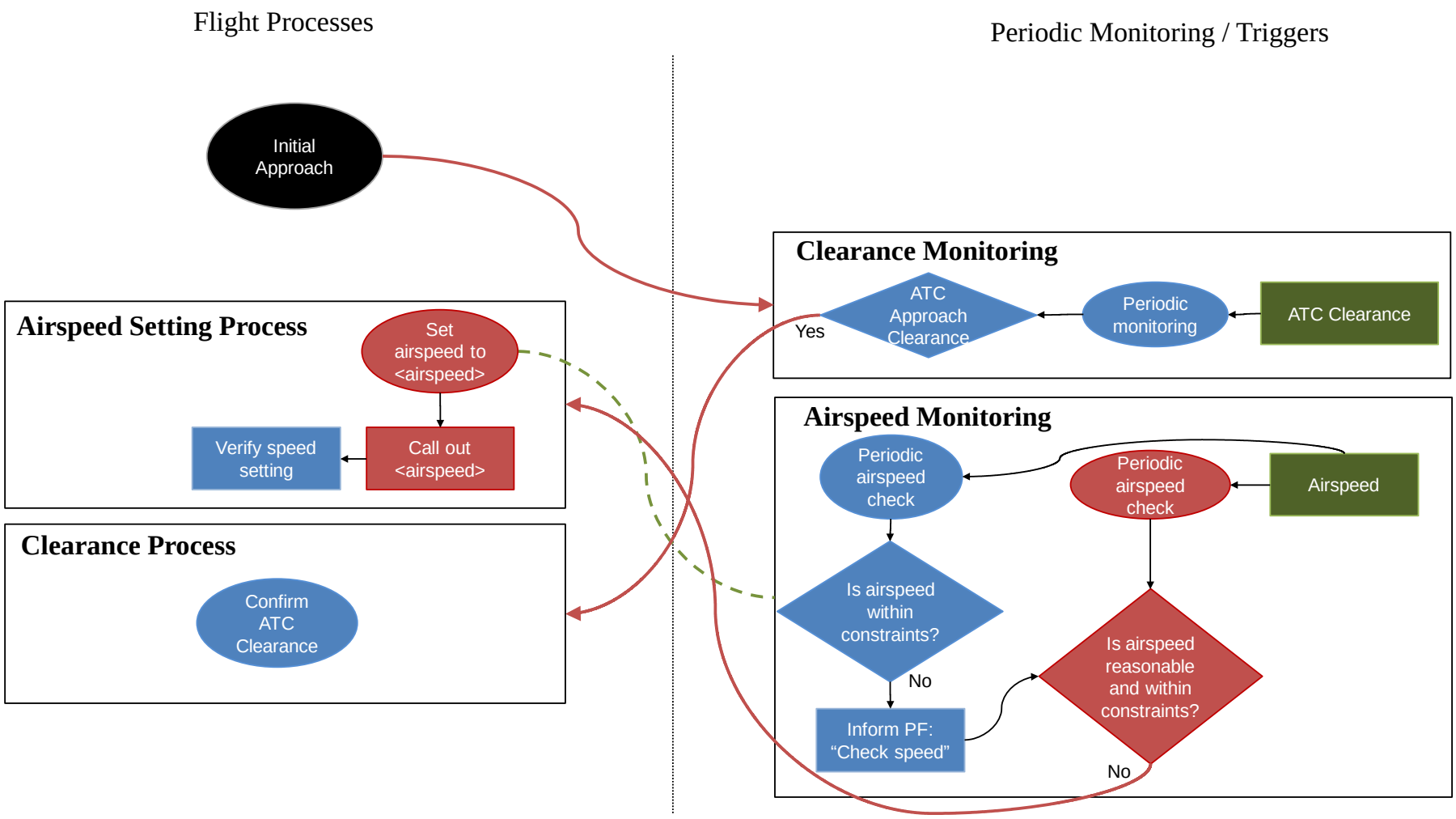


Activity Plan Components

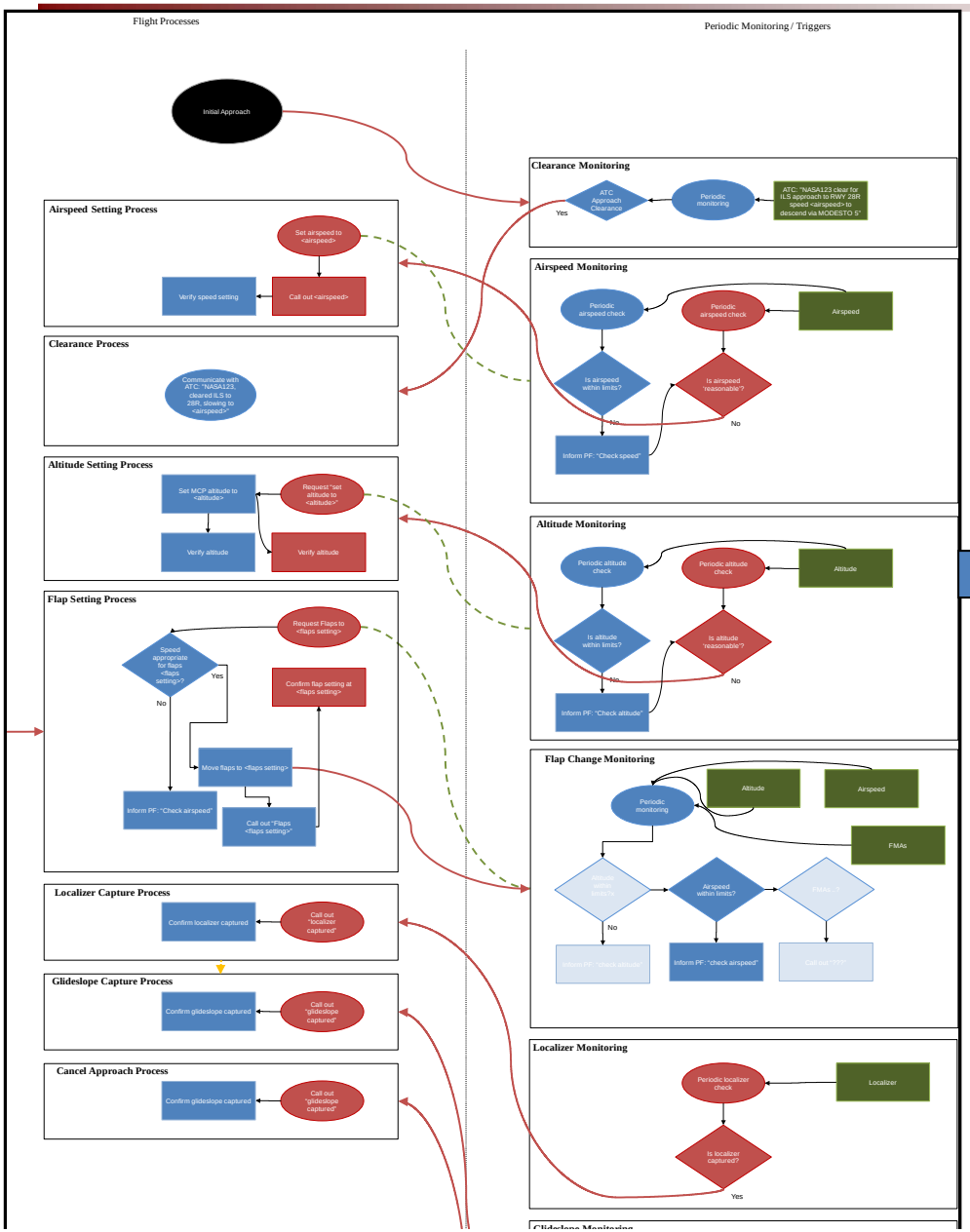
- Tasks
  - Primitive
  - Non-primitive
- Methods
  - Method T:
    Parameters: x,y
    Subtasks: T1, T2, T3, T4
    Constraints/Limitations: T1 -> T3, C -> T3
- Planner
  - Expansion of tasks using methods
  - Satisfaction of constraints



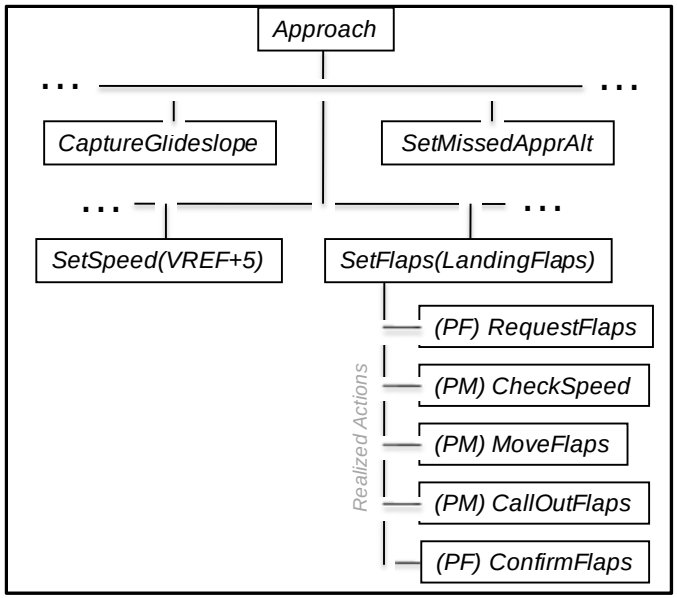
Activity Plan Construction



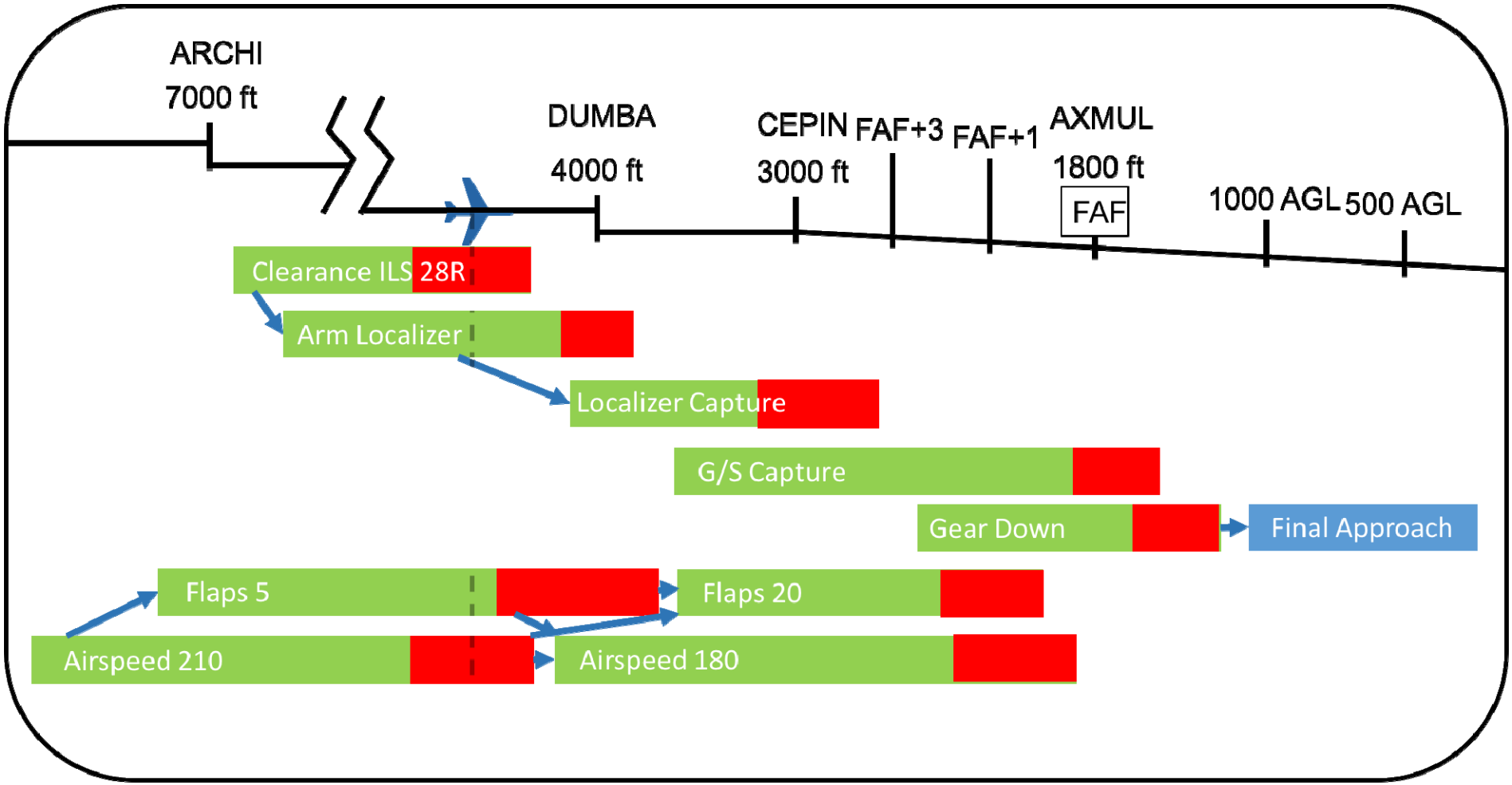
Activity Plan Construction



Translate to Hierarchy



Example Activity Plan



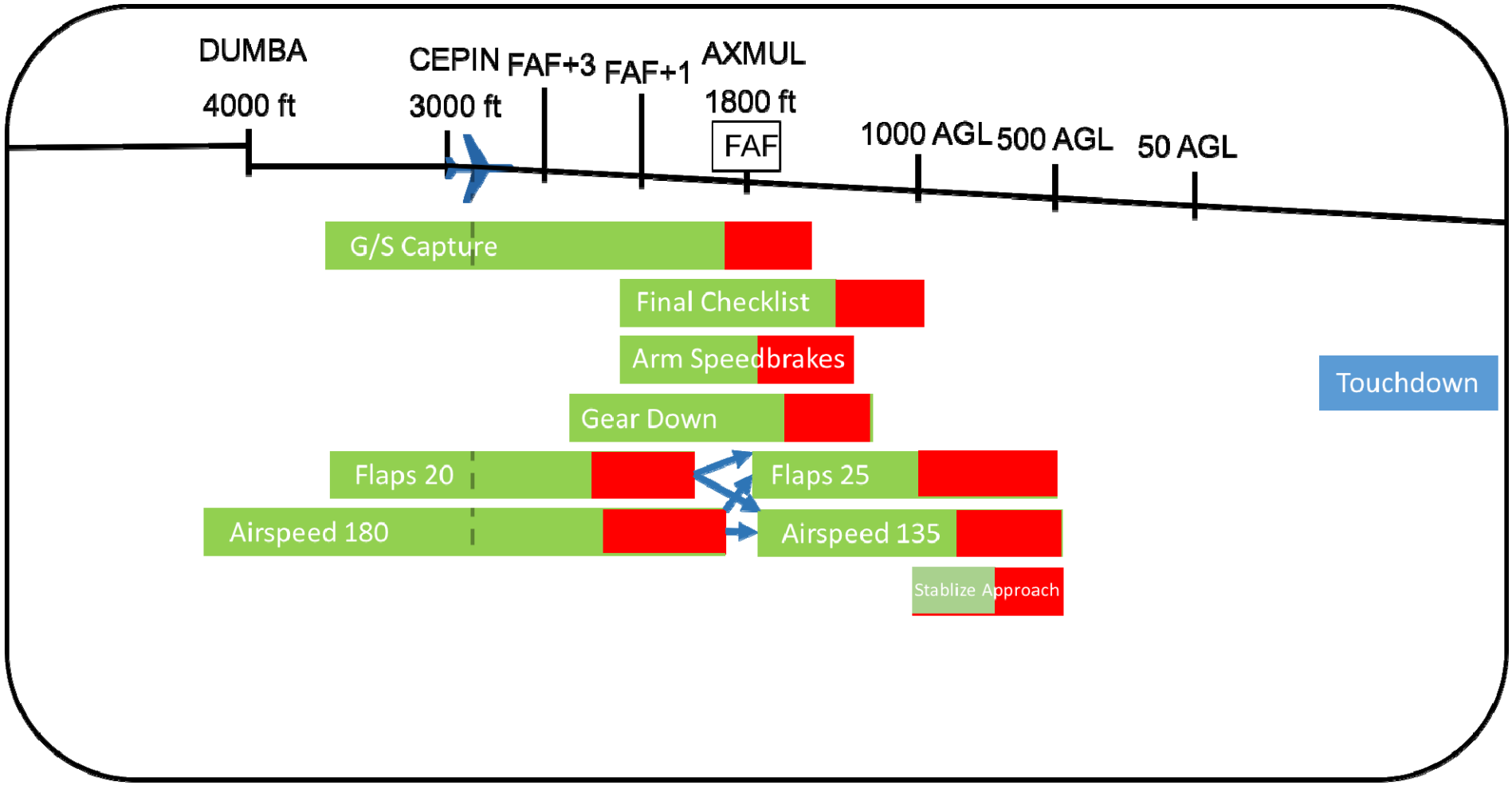
Scrolls this direction

Nominal

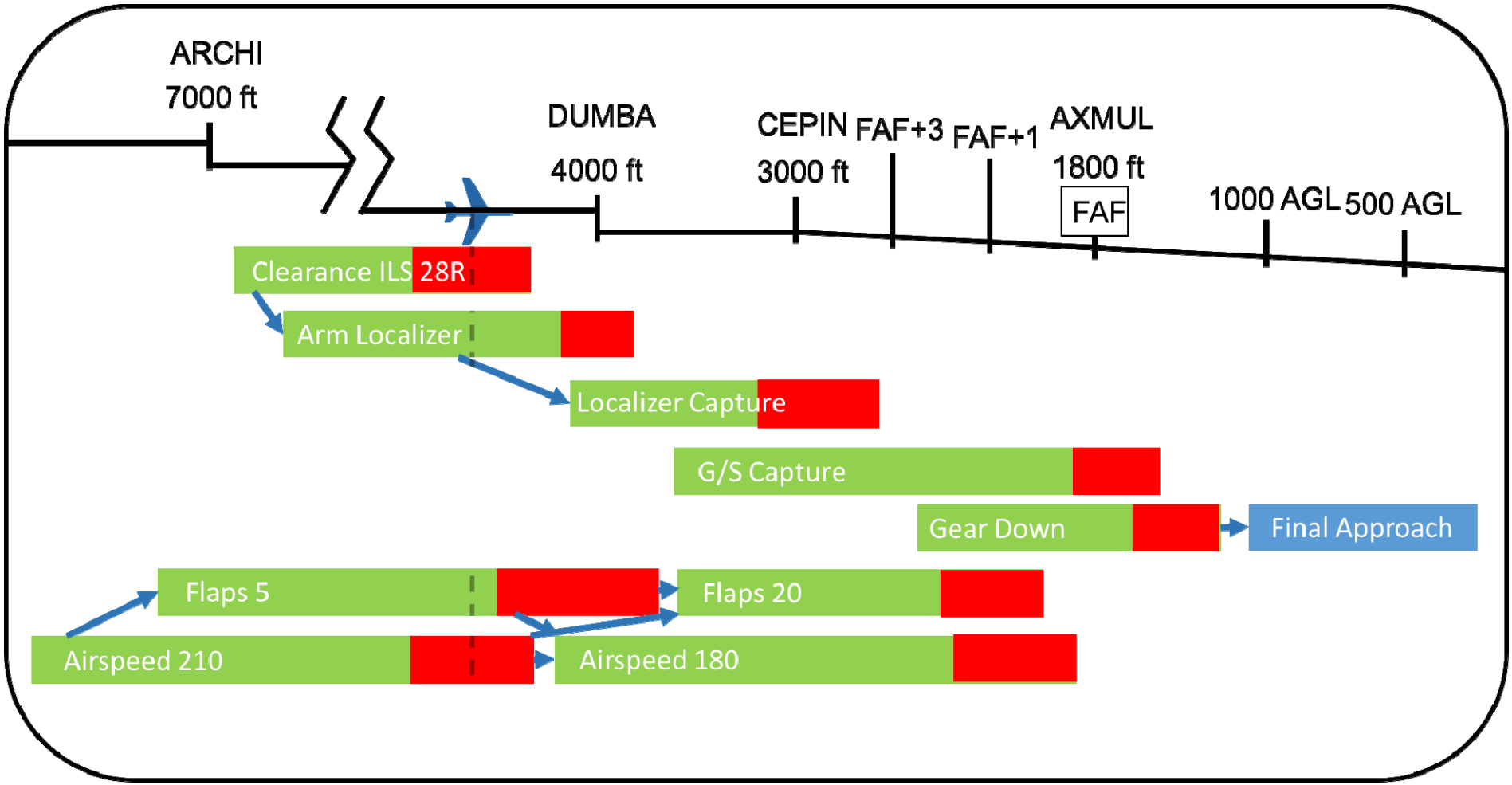
Replanning Required

Future Task Group (high level task)

Example Activity Plan



Example Activity Plan



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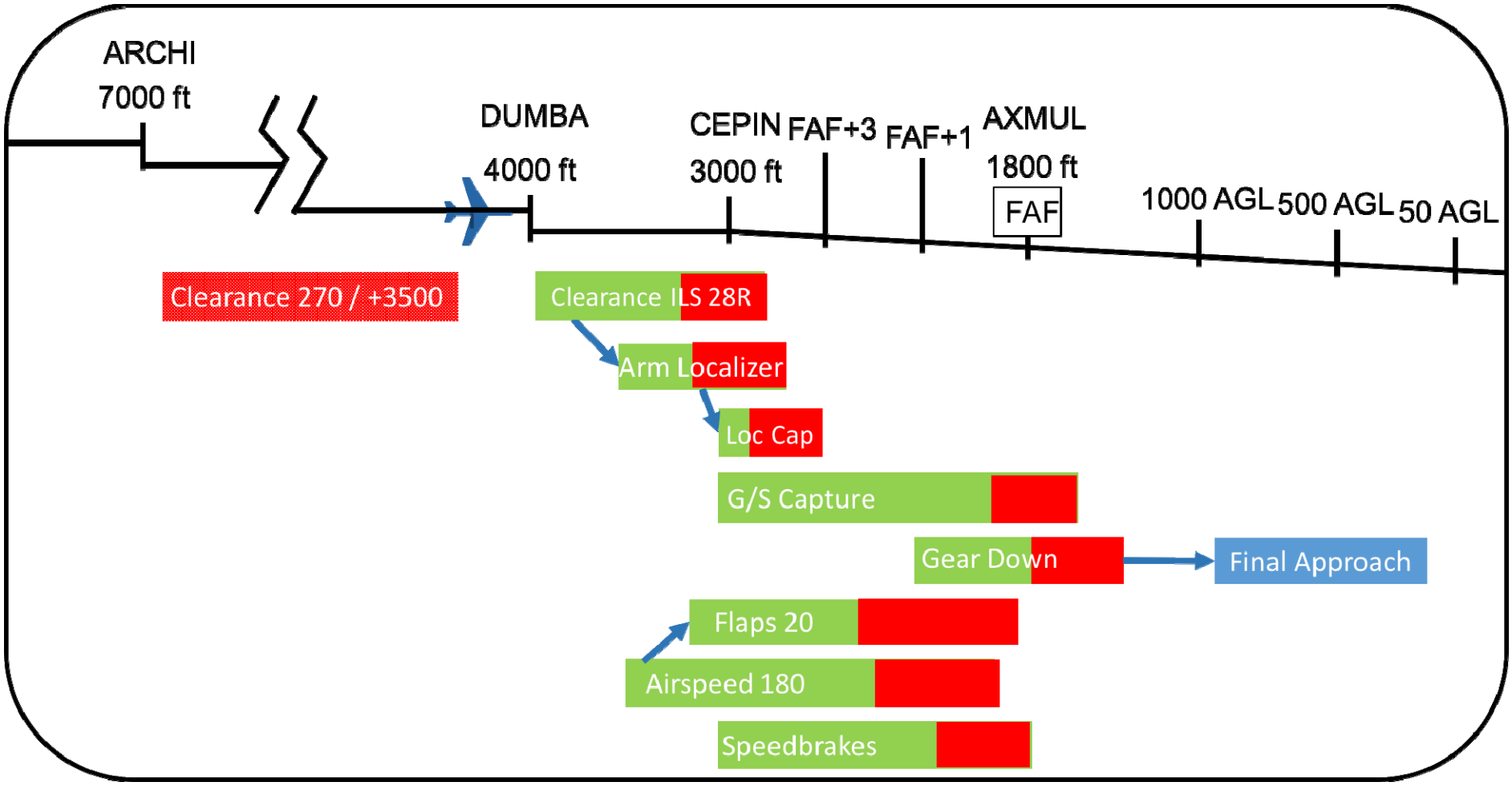
Example Activity Plan



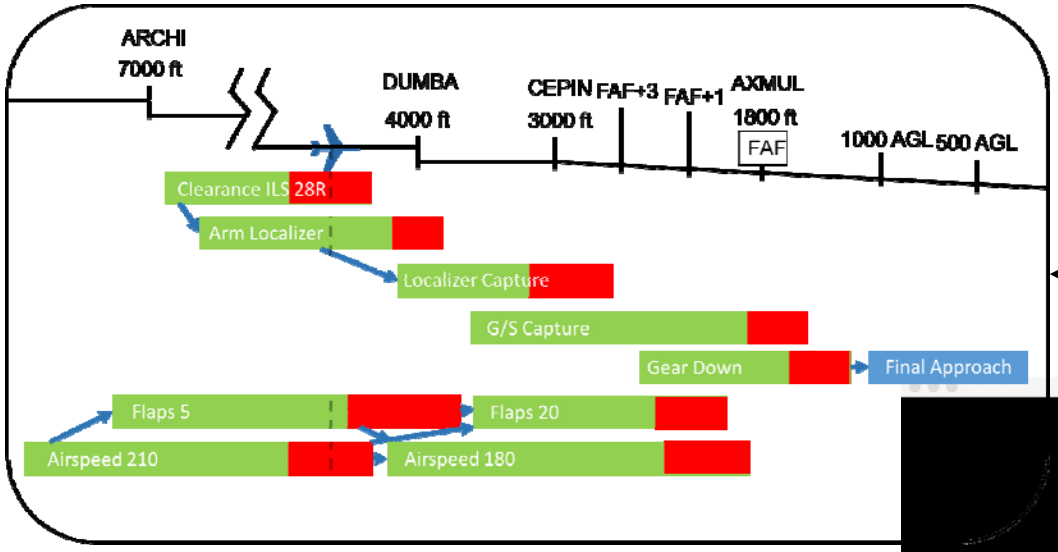
Scrolls this direction

Nominal

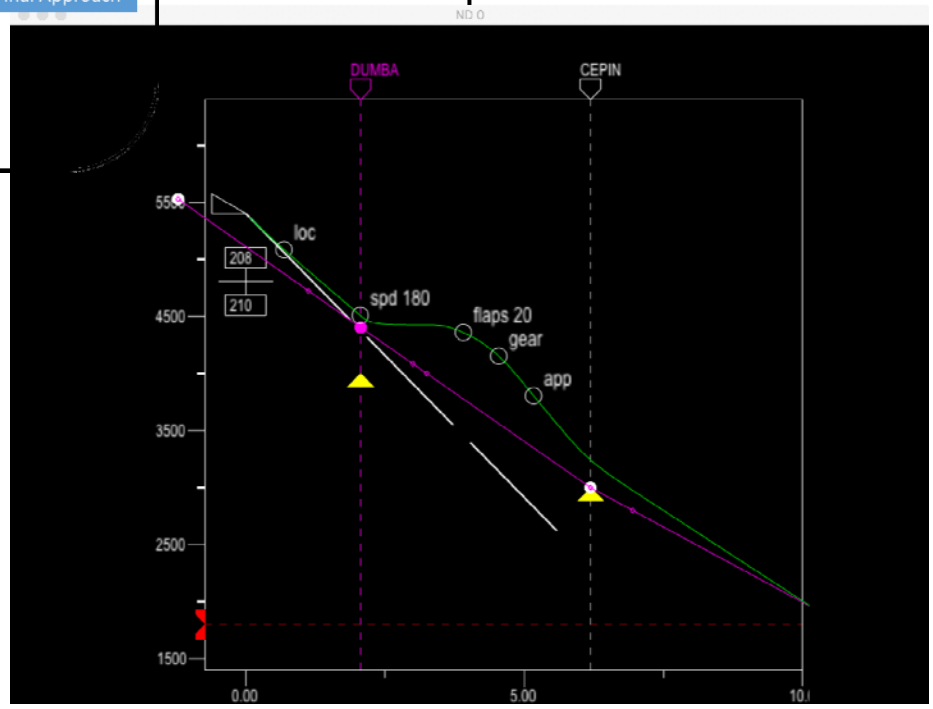
Replanning Required

Future Task Group (high level task)

Projection



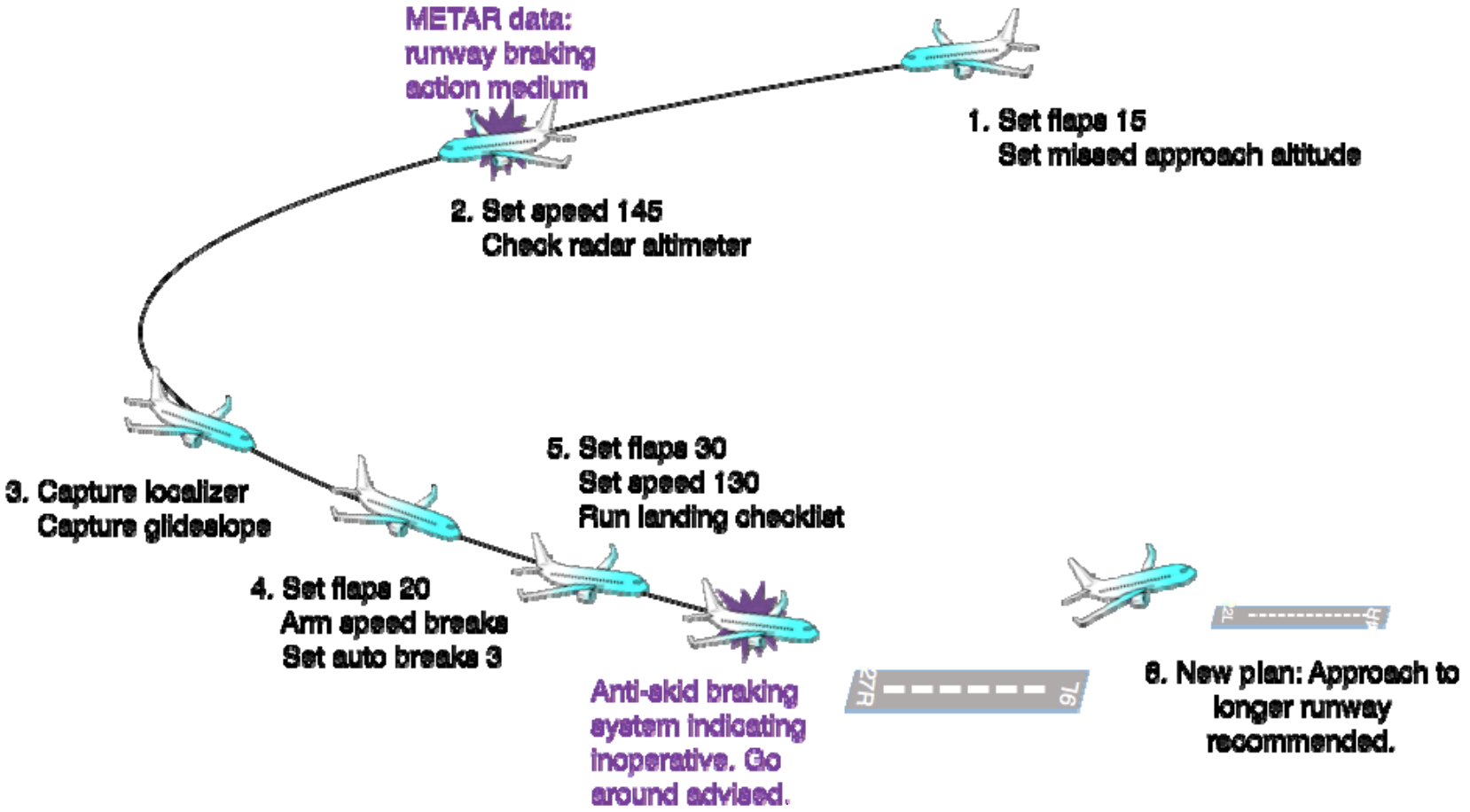
Stochastic
Sampling
& Local Search



Fast Time Simulation

Monitors and Reaction

- Execution monitors check aircraft situation
- Remedial actions to repair plan
- Unplanned Contingencies

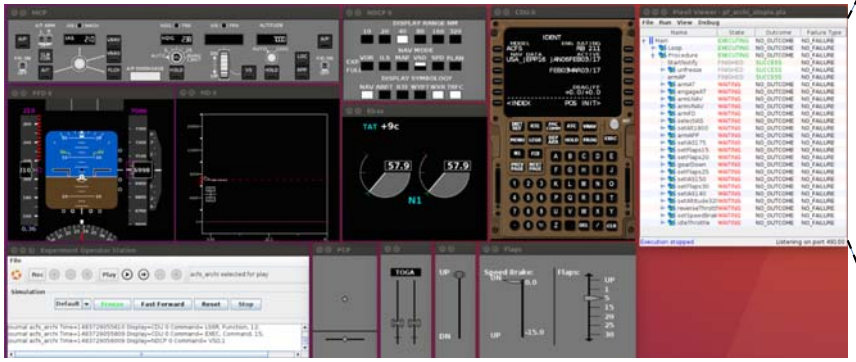


Testing & Integration

Flight Simulation Integration with PLEXIL

- Instrument monitoring
- Automated flight

Plan Execution Interchange Language



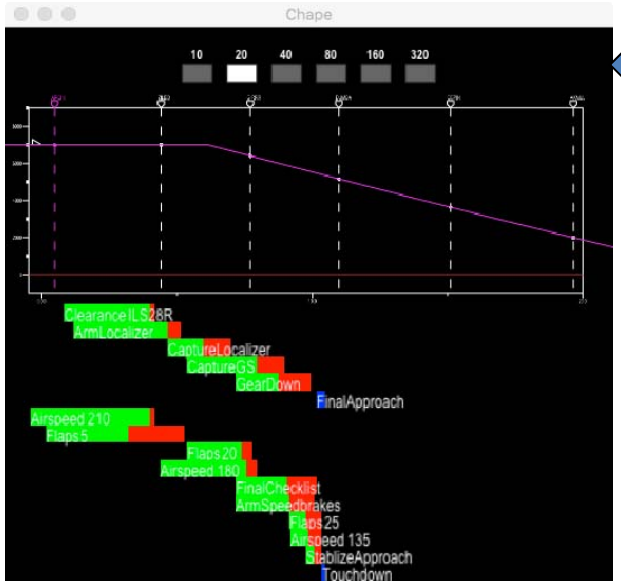
Plexil Viewer - pf_archi_simple.plx

File Run View Debug

Name	State	Outcome	Failure Type
Main	EXECUTING	NO_OUTCOME	NO_FAILURE
Loop	EXECUTING	NO_OUTCOME	NO_FAILURE
Procedure	EXECUTING	NO_OUTCOME	NO_FAILURE
StartNotify	FINISHED	SUCCESS	NO_FAILURE
unfreeze	FINISHED	SUCCESS	NO_FAILURE
armAP	FINISHED	SUCCESS	NO_FAILURE
armAT	WAITING	NO_OUTCOME	NO_FAILURE
engageAT	WAITING	NO_OUTCOME	NO_FAILURE
armLNAV	WAITING	NO_OUTCOME	NO_FAILURE
armVNAV	WAITING	NO_OUTCOME	NO_FAILURE
armFD	WAITING	NO_OUTCOME	NO_FAILURE
selectIAS	WAITING	NO_OUTCOME	NO_FAILURE
setAlt1800	WAITING	NO_OUTCOME	NO_FAILURE
armAPP	WAITING	NO_OUTCOME	NO_FAILURE
setIAS175	WAITING	NO_OUTCOME	NO_FAILURE
setFlaps15	WAITING	NO_OUTCOME	NO_FAILURE
setFlaps20	WAITING	NO_OUTCOME	NO_FAILURE
gearDown	WAITING	NO_OUTCOME	NO_FAILURE
setFlaps25	WAITING	NO_OUTCOME	NO_FAILURE
setIAS150	WAITING	NO_OUTCOME	NO_FAILURE
setFlaps30	WAITING	NO_OUTCOME	NO_FAILURE
setIAS140	WAITING	NO_OUTCOME	NO_FAILURE
setAltitude32(	WAITING	NO_OUTCOME	NO_FAILURE
reverseThrottl	WAITING	NO_OUTCOME	NO_FAILURE
setSpeedBrak	WAITING	NO_OUTCOME	NO_FAILURE
idleThrottle	WAITING	NO_OUTCOME	NO_FAILURE

Execution stopped — Listening on port 49100

Debug Tool



Transition to UI

Prototype UI Design

- Timeline view
- Gantt chart style
  - Based on location of aircraft
  - Timeline of best start times (not duration)
- Matches with trajectory vertical profile and waypoints

Aircraft Capability Management

Randy Mumaw
Michael Feary

February 16, 2017

Common Themes

- Focus on Operational Decision Making
- Evolution from Pilot Decision Support to Human-Autonomy Teaming

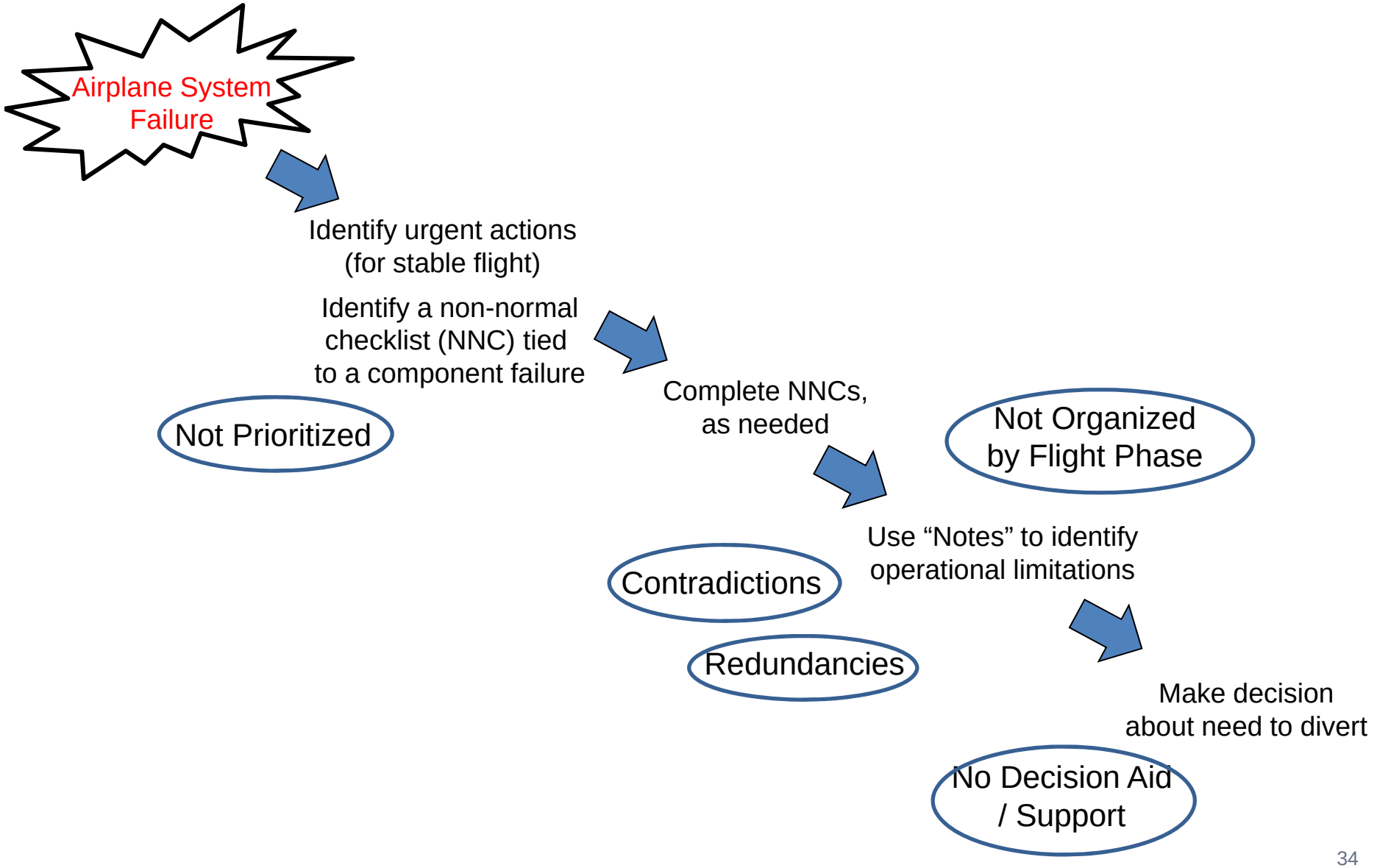
Explosion of Alert Messages

Qantas A380 Uncontained Engine Failure

- QF 32; Singapore to Sydney; 469 people on board
- 4 minutes after Take-off, engine no. 2 bursts, severely damaging other equipment
- 43 ECAM messages in first 60 seconds; 10 additional later
- 50 minutes to sort through the non-normal checklists (NNCs)

"It was hard to work out a list of what had failed; it was getting to be too much to follow. So we inverted our logic: Instead of worrying about what failed, I said 'Let's look at what's working.'" *A380 Captain*

Current Approach to Aircraft System Alerting



What is a Capability?

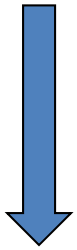
Airplane System Components

- Hydraulic system
- Thrust Reverser
- Battery
- Air conditioning pack

Airplane Capabilities

- Range / Endurance
- Stopping Distance (on runway)
- Ability to perform a specific approach
- Ability to enter RVSM airspace

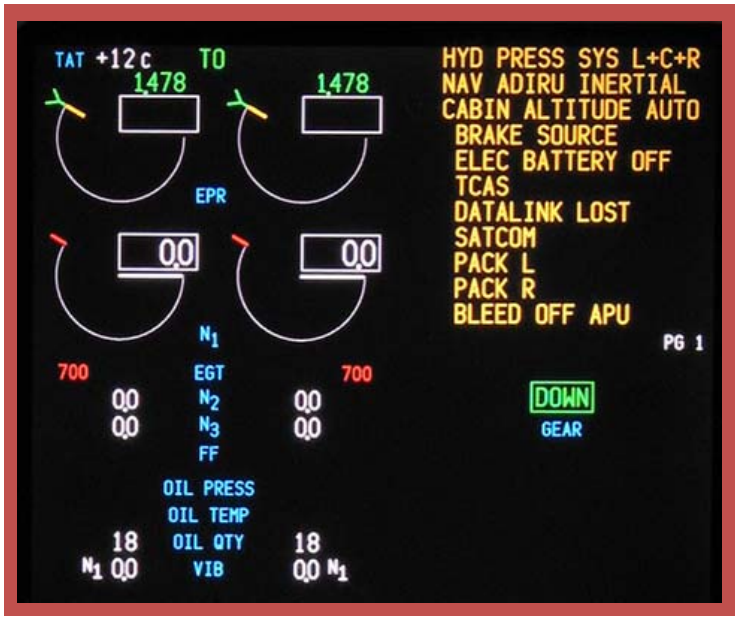
Airplane system components have failed



What can I do?
Where can I go?

Explicit Alerting on Capabilities

Typically, we don't



Can I Fly?

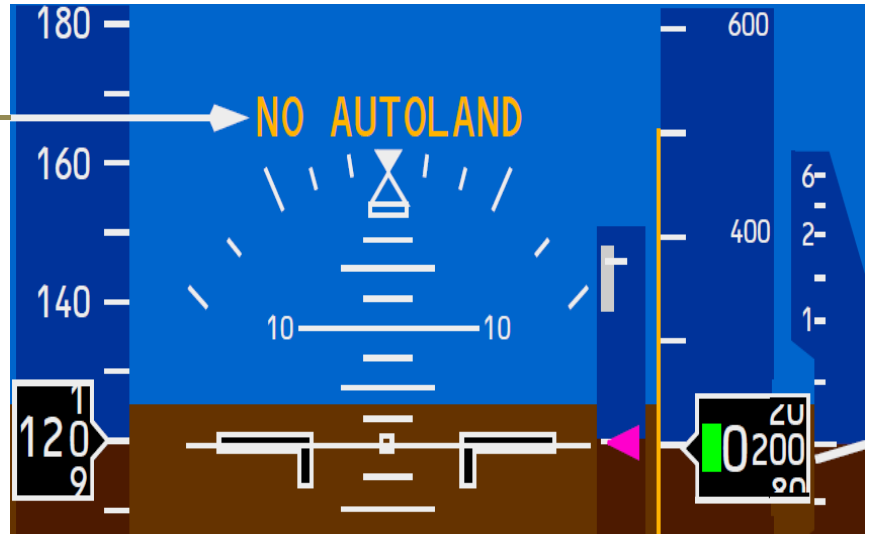
- 787
  - 449 EICAS messages (Warning, Caution, Advisory)
  - All but 19 of them reflect physical system failures/ status changes

Explicit Alerting on Capabilities

Sometimes, we do . . . .

Examples from the 787

- NO AUTOLAND
- NO LAND 3
- NAV UNABLE RNP
- STALL PROTECTION



The New Generation of Systems is Different

So are the pilots . . . .

Airplane System Integration  Pilot System Knowledge 

- Airplanes have become more integrated–more shared resources, more interconnections–and failures can have effects that are difficult to anticipate or understand
- The volume and rate of crew alert and status messages can increase significantly for certain types of failures
- Non-normal procedure design for combinations of failures is challenging
- Air turnbacks or diversions occur due to confusion about severity of the failures, and impact on the mission

<u>Both types of errors occur:</u>
- Poor understanding of real problems
- Oversensitivity to trivial changes

Three Types of Information for the Pilot

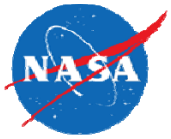
Answering Basic Questions

- **Status of Airplane Capabilities**
  - What is working/what is not?
  - How can I restore what has been lost?
- **Operational Guidance**
  - Which limitations do I need to observe during the remainder of the mission?
- **Mission Objectives**
  - Can I still complete the planned mission?
  - If not, where else can I land?

An Alternative Approach

Time Horizon 1	Time Horizon 2	Time Horizon 3
Identify urgent actions (for stable flight)		
Present an overview of airplane capabilities (in addition to EICAS/ECAM)	Identify operational limitations by flight phase	Decision Support for Mission Decision
Goals: reconfigure systems to restore as much capability as possible; understand generally what is possible	Goals: operate with an understanding of ops limitations for remaining flight; do not "fly into" new problems	Goals: understand where you can go and where is "best" to go; look at trade-offs; understand risks
Dynamic	Organized by Phase of Flight	Integrate Airplane Capabilities with Airport, Weather, NOTAMS, etc
Prioritized NNC selection	Ability to Look Ahead for Limitations	Identify "Compatible" Airports within Range

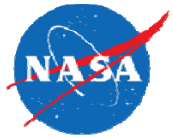
Thinking about Human-Autonomy Teaming



- Initially, we pull together information relevant to mission/diversion; e.g.,
  - airplane compatibility / capability (range)
  - airport information
  - weather information
- Then, organize it in a way that flight crews can benefit, understanding how to present it to support collaborative decision making
- Finally, transition some elements to a more autonomous advisor

Planned Activities

- Develop a “framework/language” for communicating airplane capabilities
  - Pilot interviews and prototyping
- Develop a small set of failure cases
- Develop system models to simulate system failures
- Collaborate with industry (e.g. SAA with Boeing)



Thank you