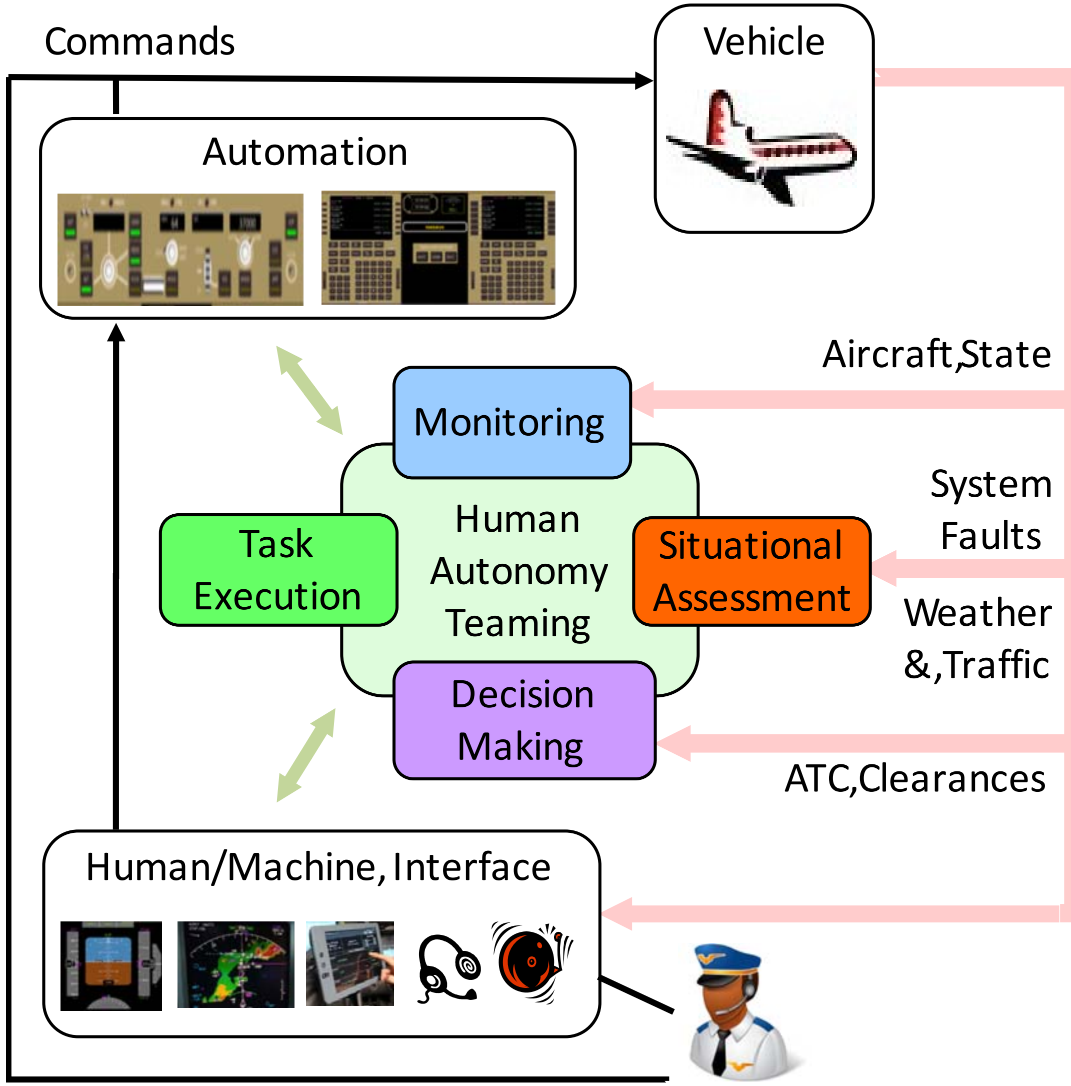
Understanding Human Autonomy Teaming Through Applications

Bimal Aponso, NASA Ames Research Center



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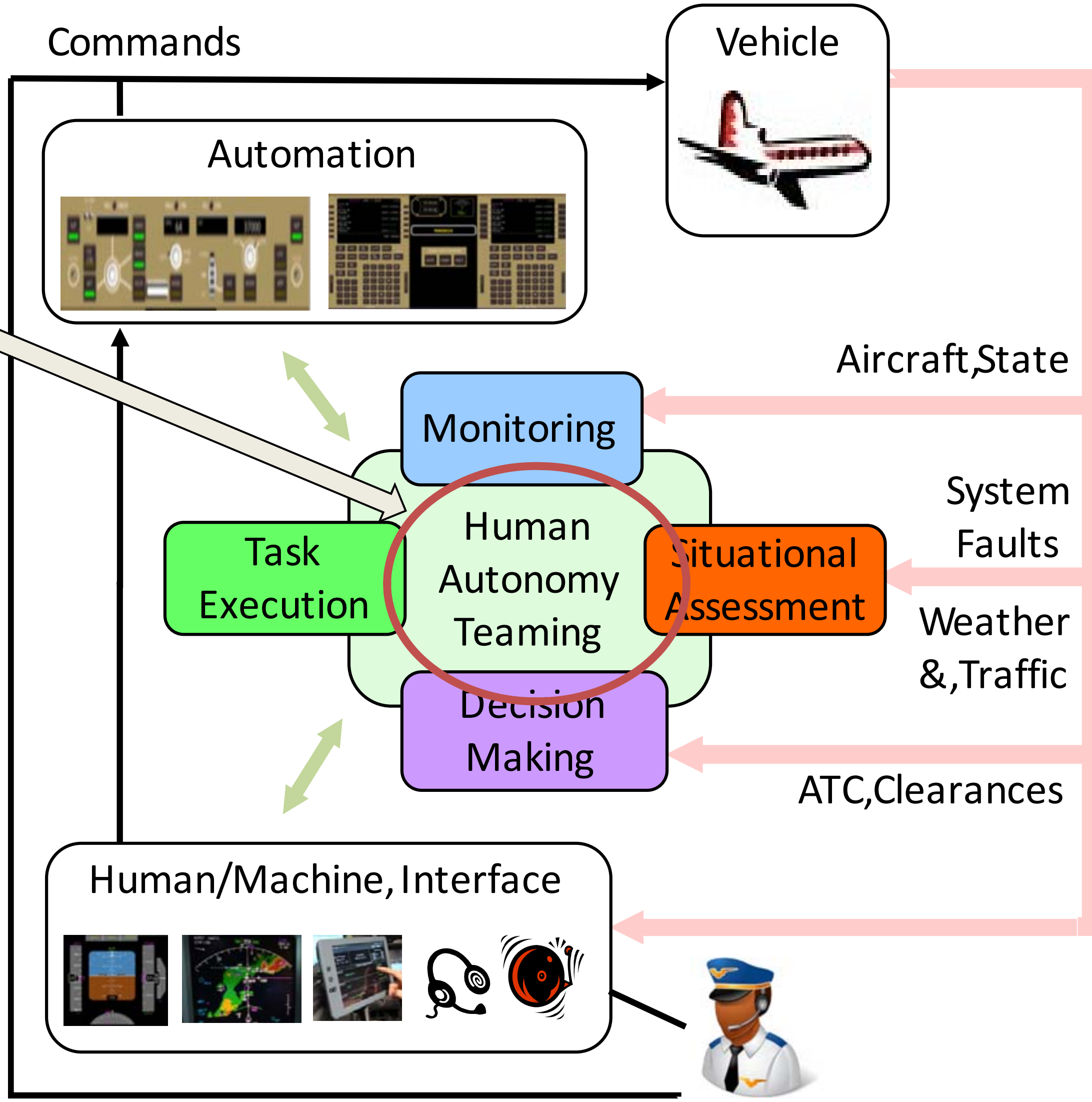
Framework for Human Autonomy Teaming

Summer Brandt
Joel Lachter



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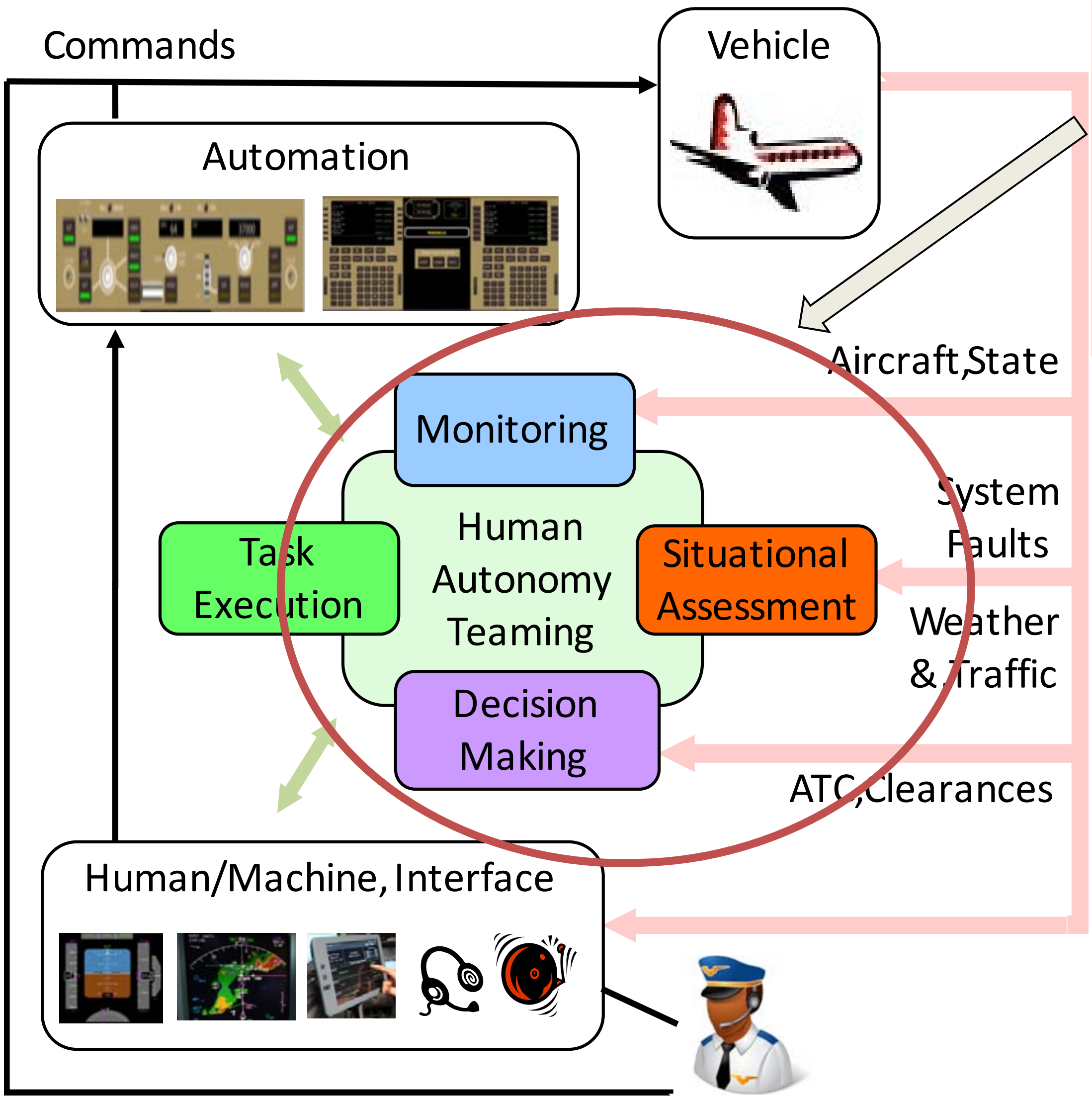

Cockpit Activity Planning

J Benton

John Kaneshige

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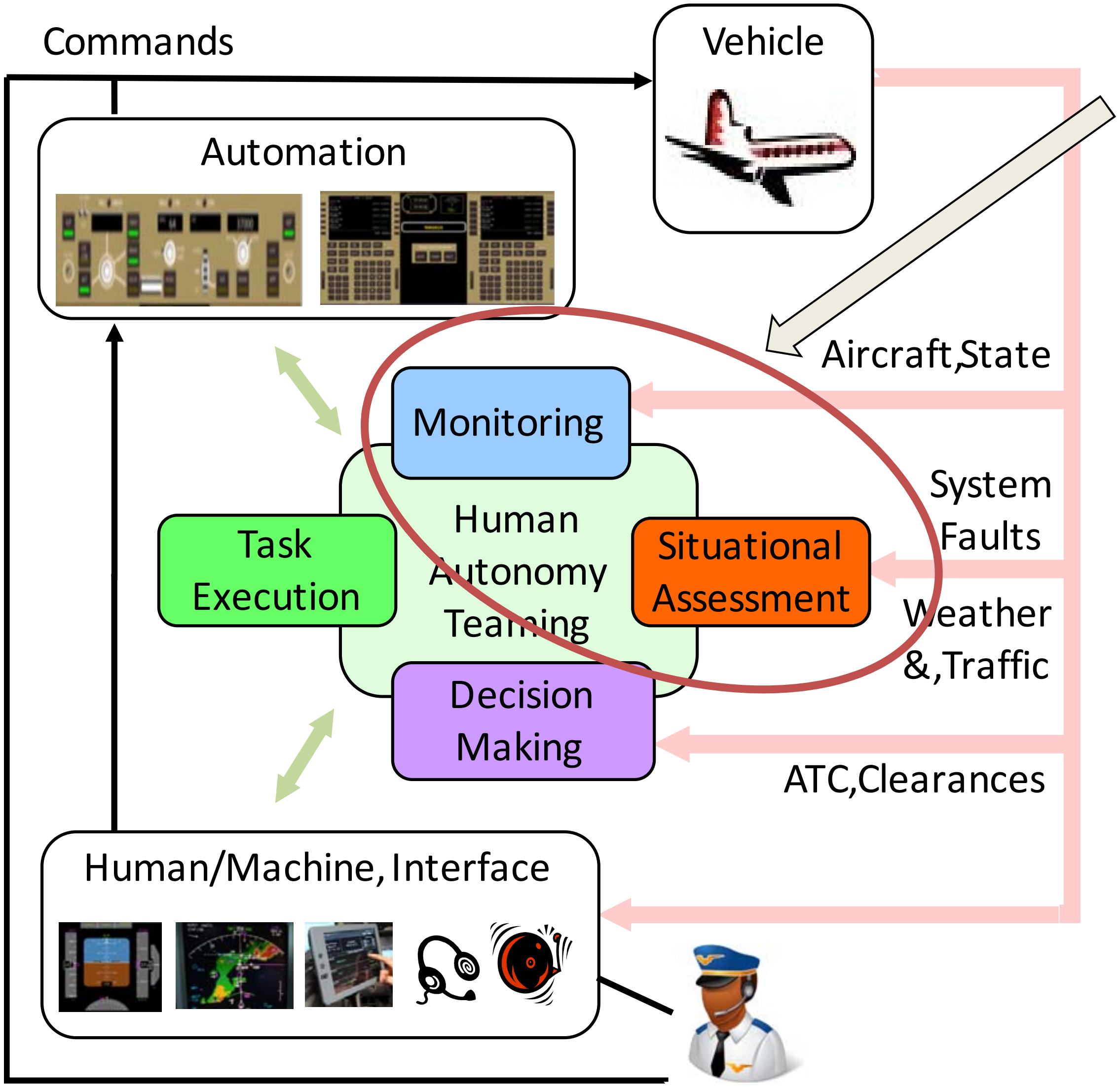


Aircraft Capability Management

Randy Mumaw

Mike Feary

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

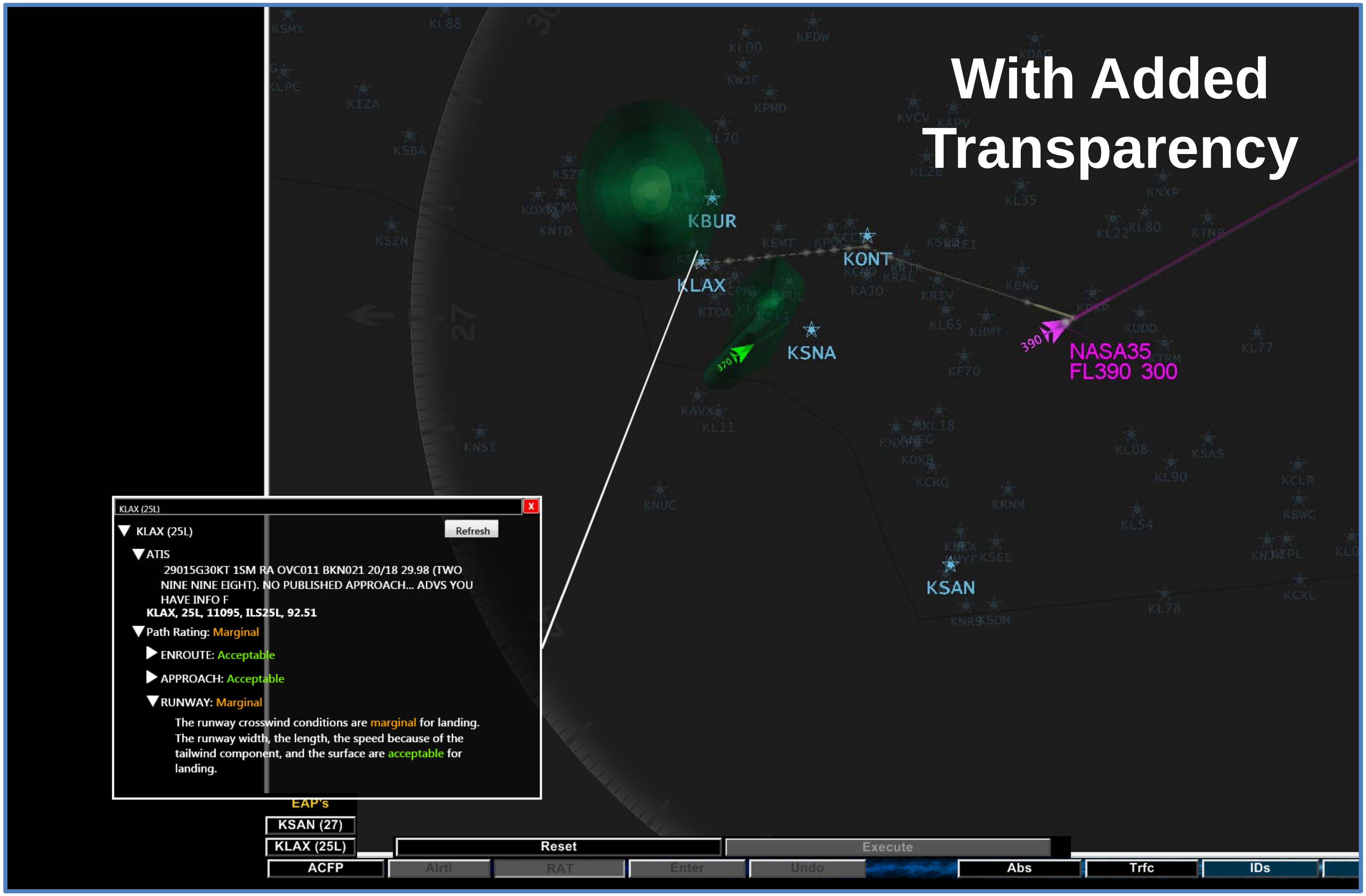
- Brittle
  - **Negotiated decisions** puts a layer of human flexibility into system behavior
- Opaque
  - Requires that systems be designed to be **transparent**, present **rationale** and confidence
  - Communication should be in terms the operator can easily understand (**shared language**)
- Miscalibrated 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

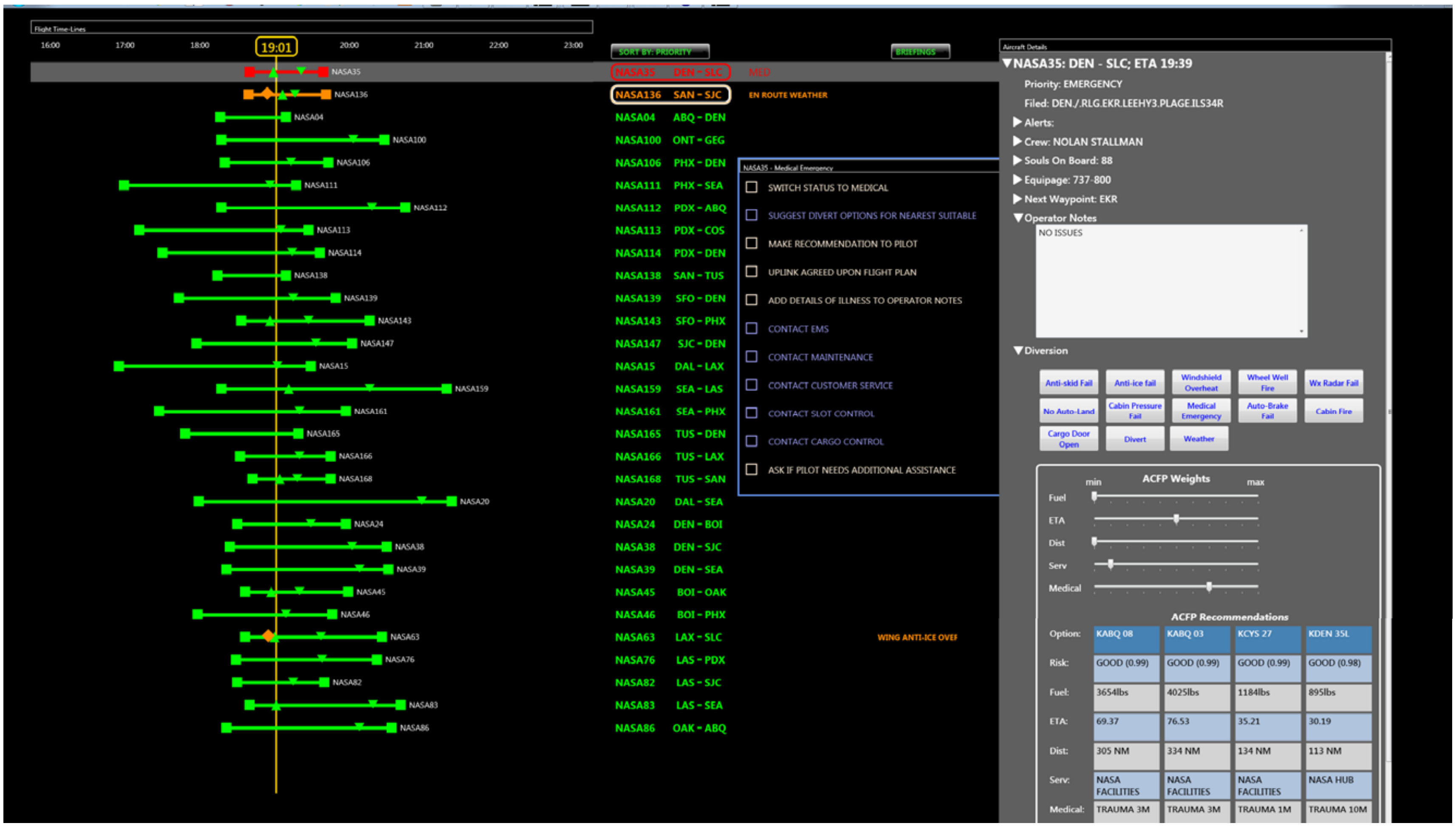
Autonomous Constrained Flight Planner (ACFP)

Recommended airports
- rank ordered.

Adding HAT Principles to the Ground Station

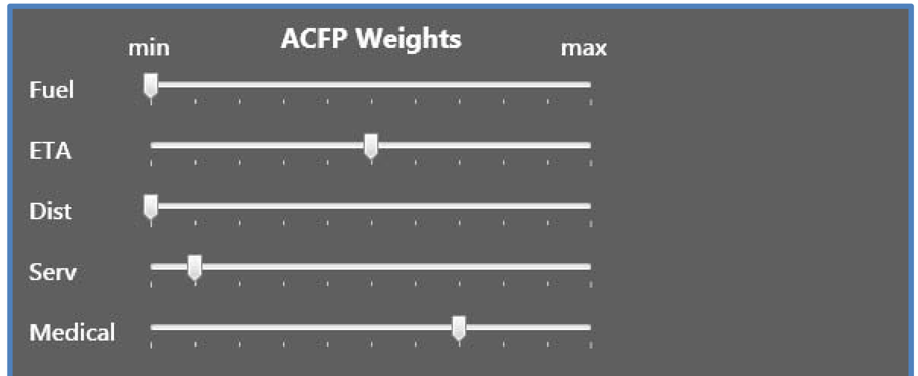


Adding HAT Principles to the Ground Station



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.

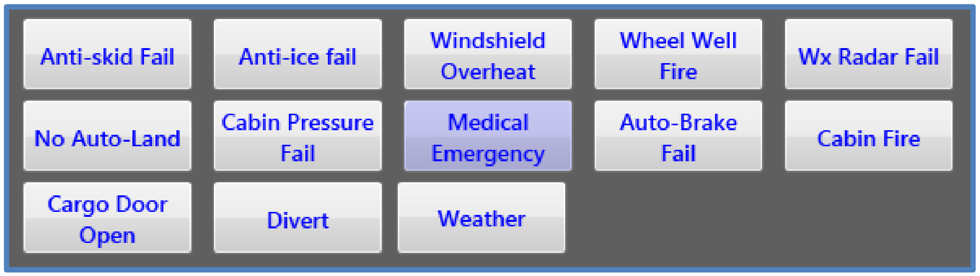


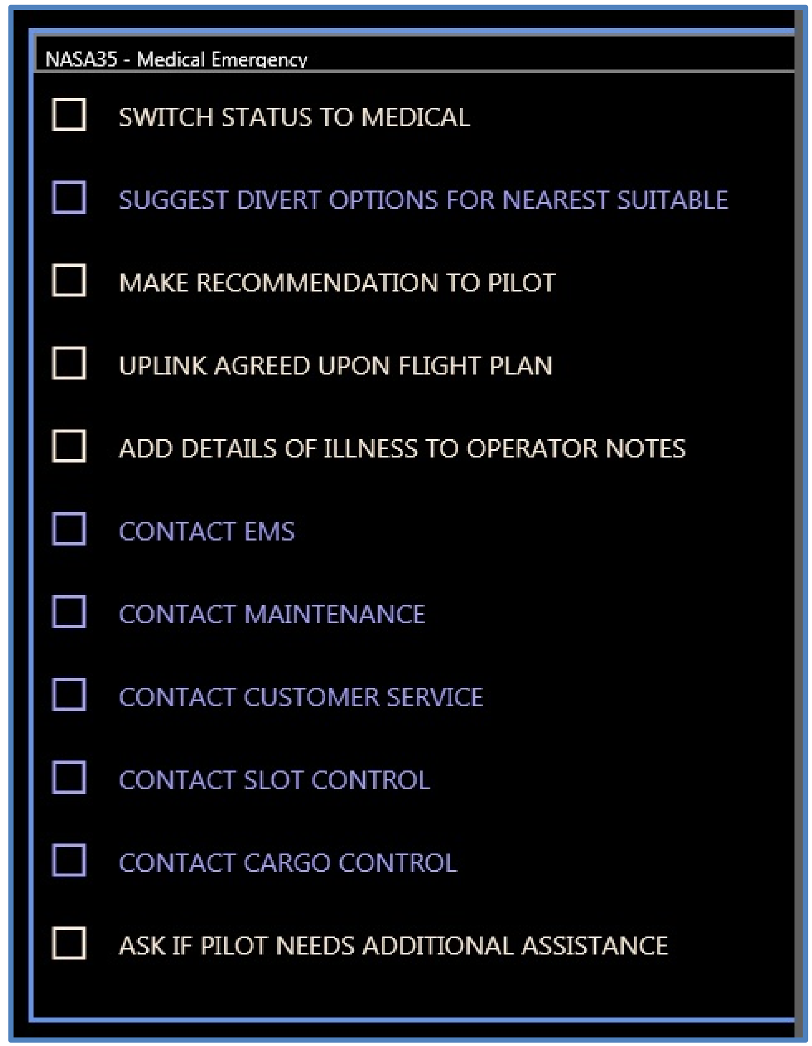
ACFP Recommendations

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

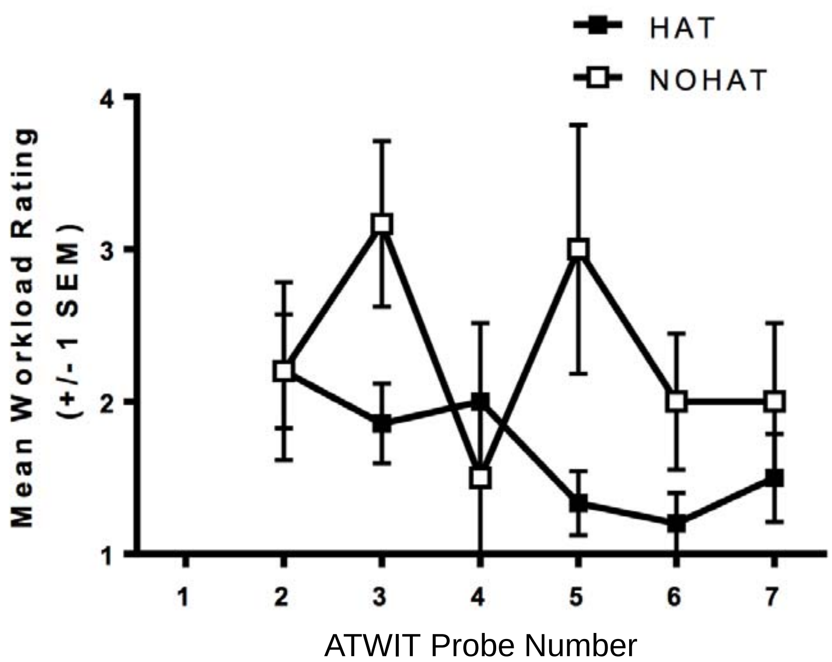
- Participants, with the help of automation, monitored 30 aircraft
  - Alerted pilots when
    - Aircraft was off path or pilot failed to comply with clearances
    - Significant weather events affect aircraft trajectory
    - Pilot failed to act on EICAS alerts
  - Rerouted aircraft when
    - Weather 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)

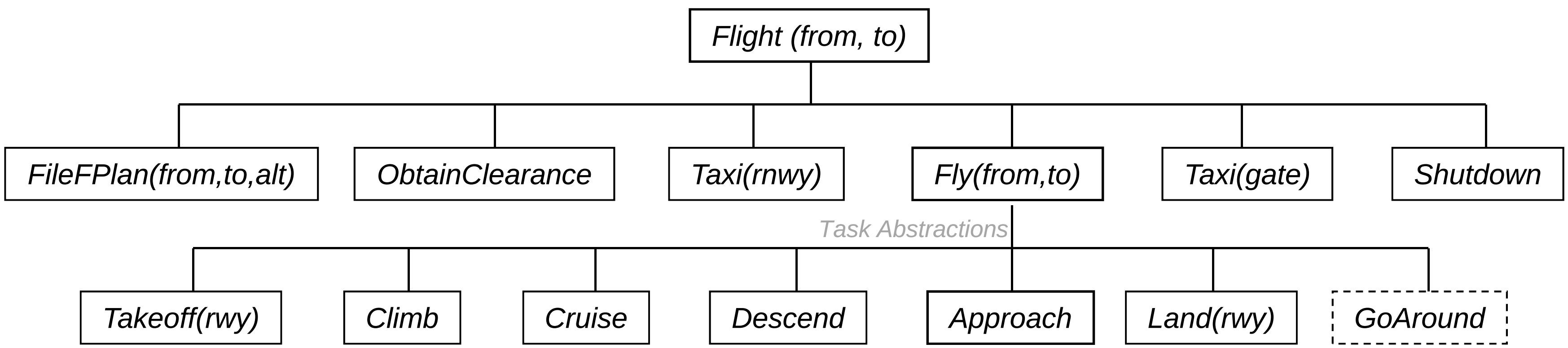
Cockpit Hierarchical Activity Planning and Execution

J Benton
John Kaneshige

February 16, 2017

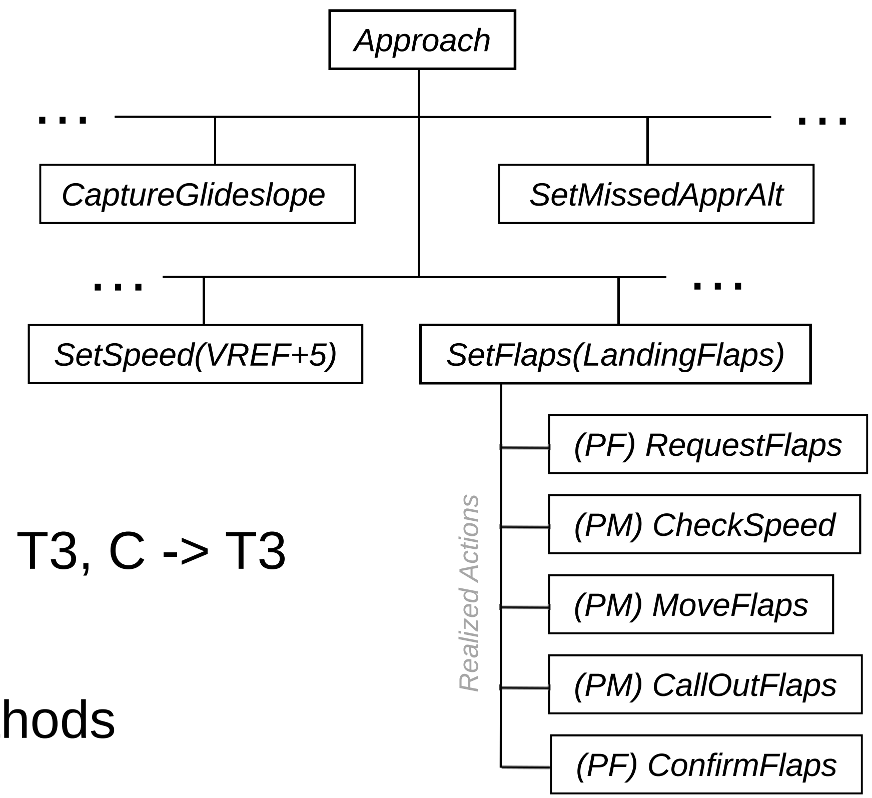
Hierarchical Activity Planning

- 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

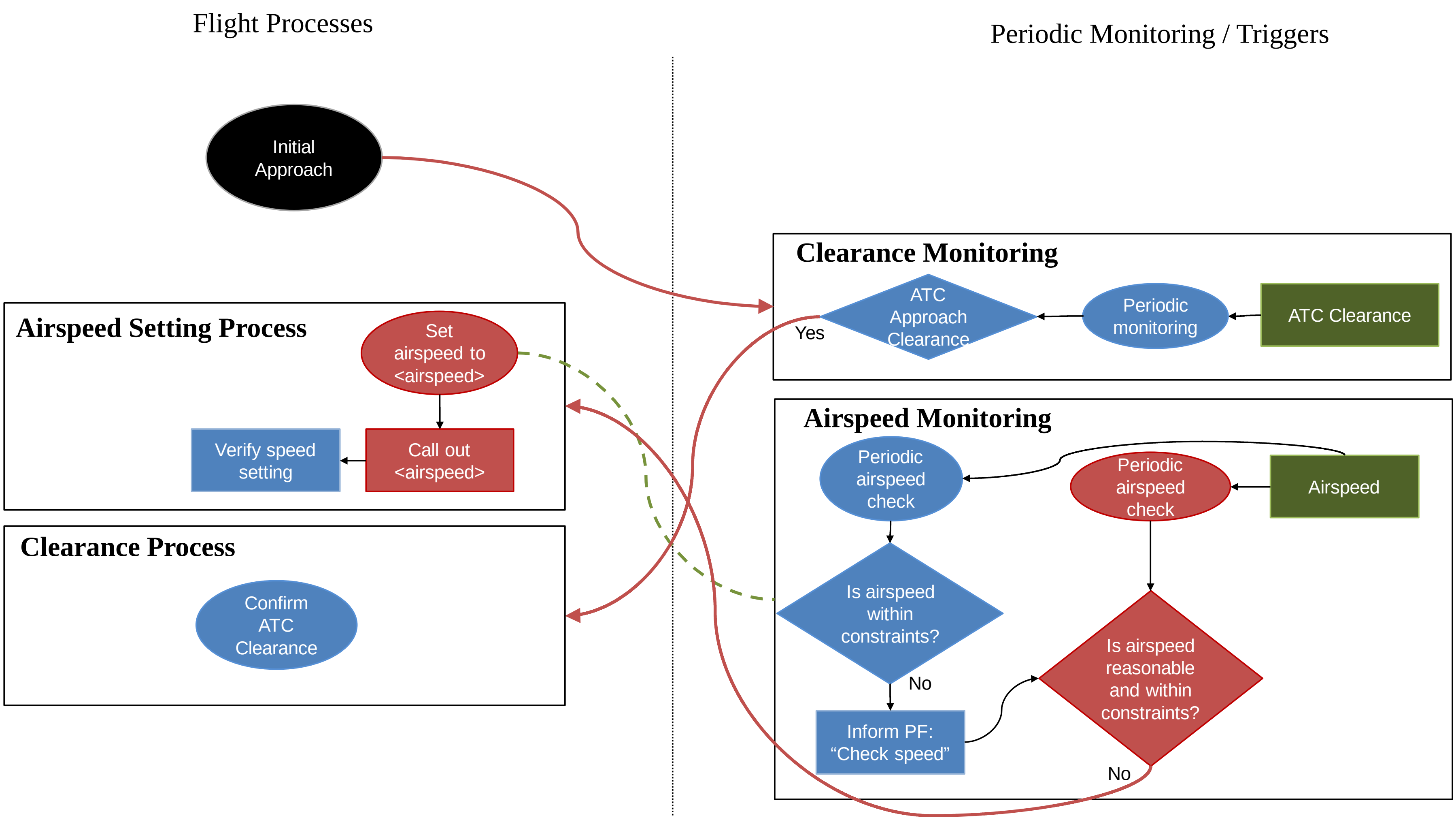


Activity Plan Components

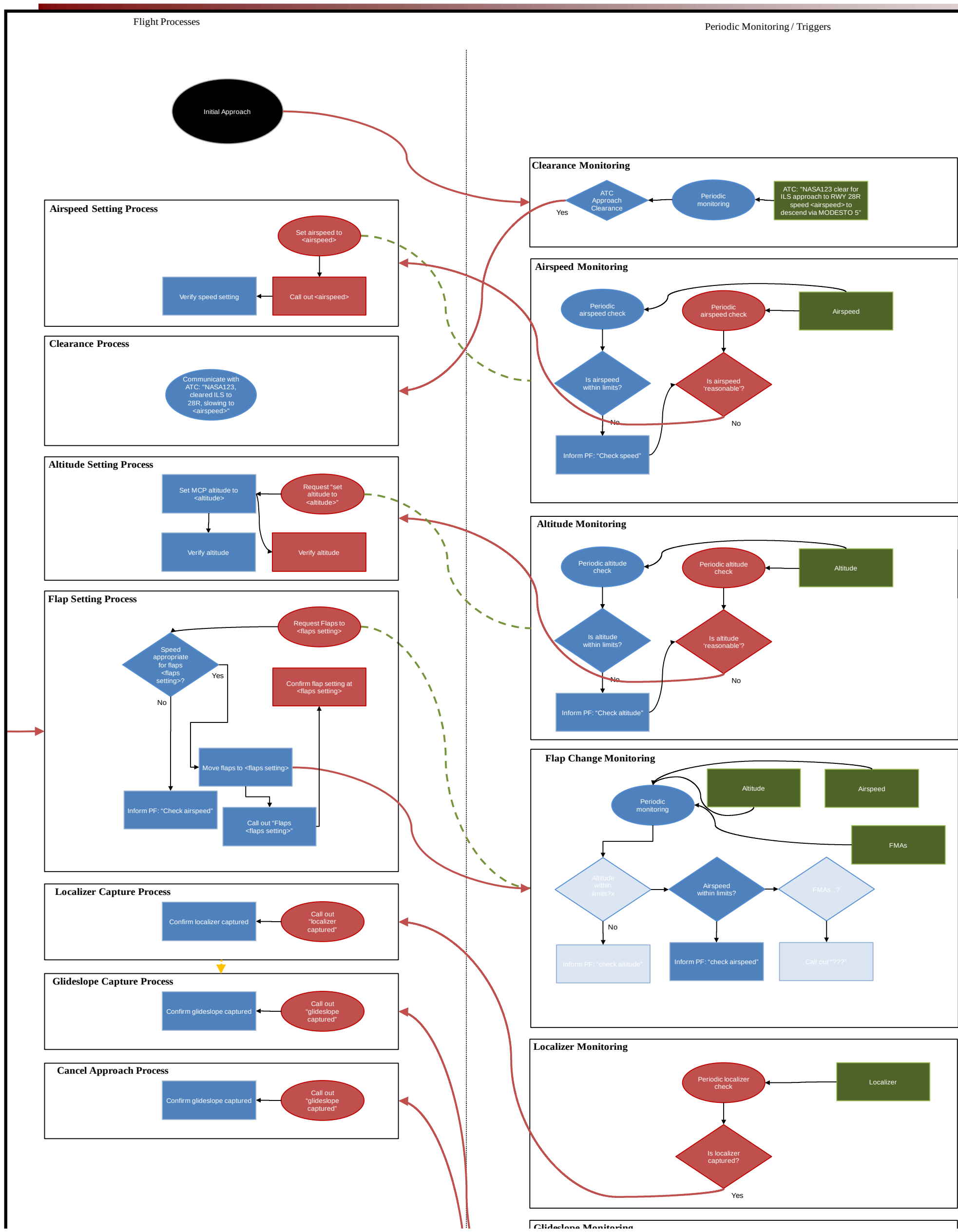
- Tasks
  - Primitive
  - Non-primitive
- Methods
  - Method T:
    Parameters: x,y
    Subtasks: T1, T2, T3, T4
    Constraints/Limitations: T1 -> T3, C -> T3
- Planner
  - Expansion of tasks using methods
  - Satisfaction of constraints



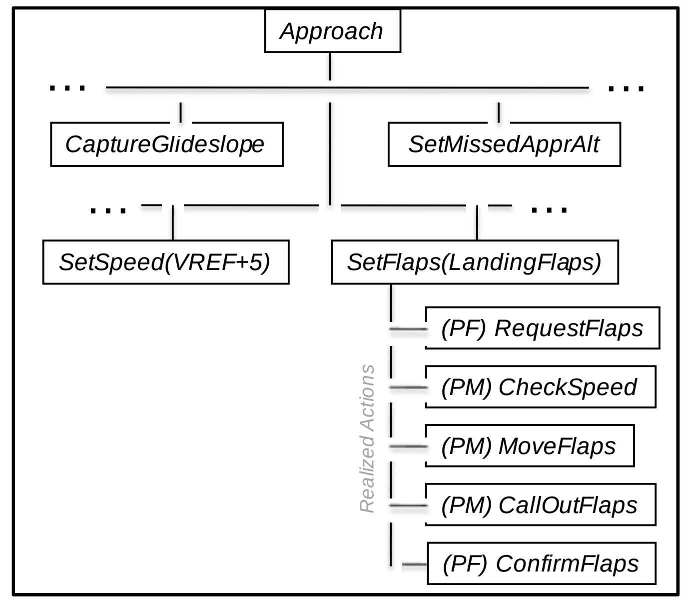
Activity Plan Construction



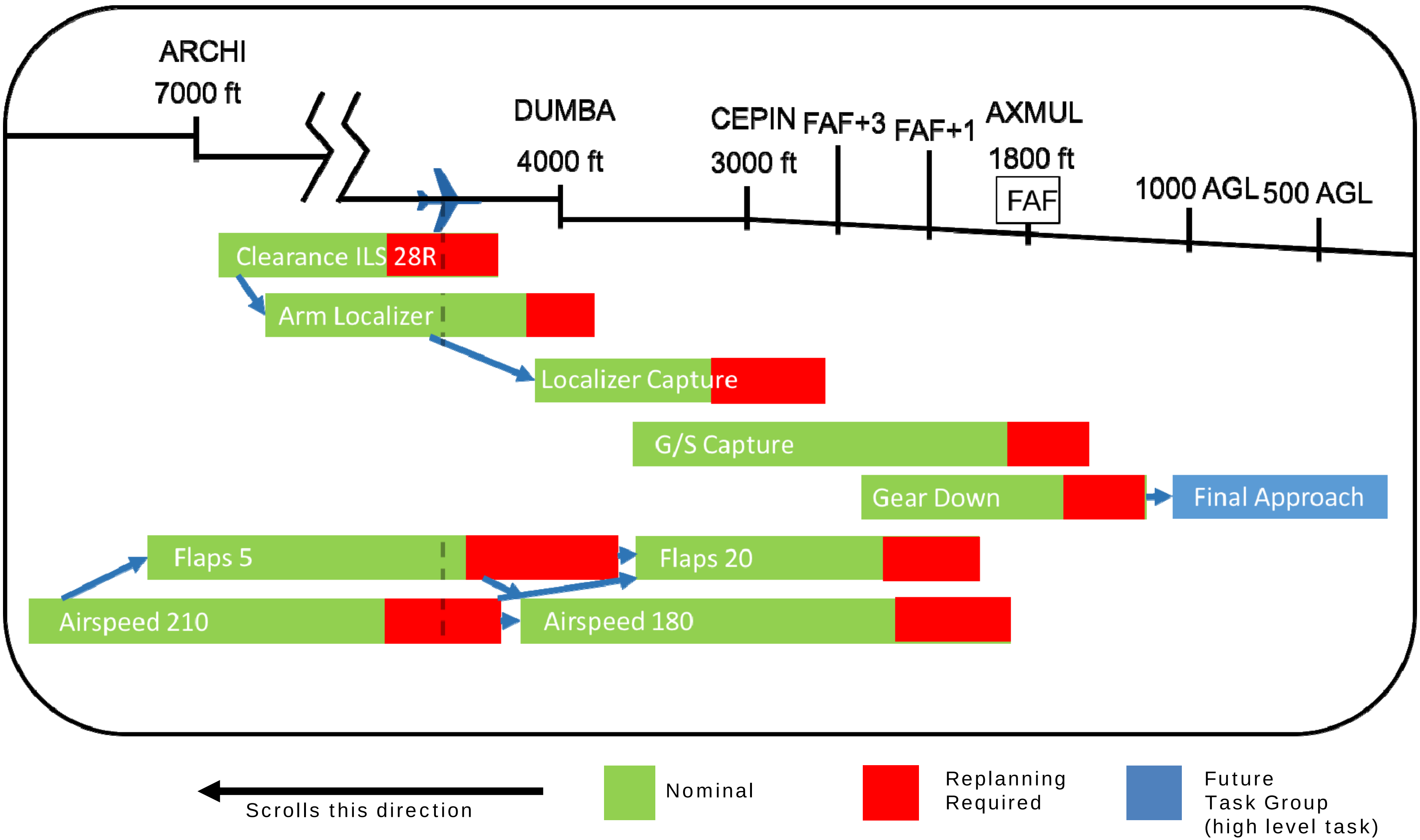
Activity Plan Construction



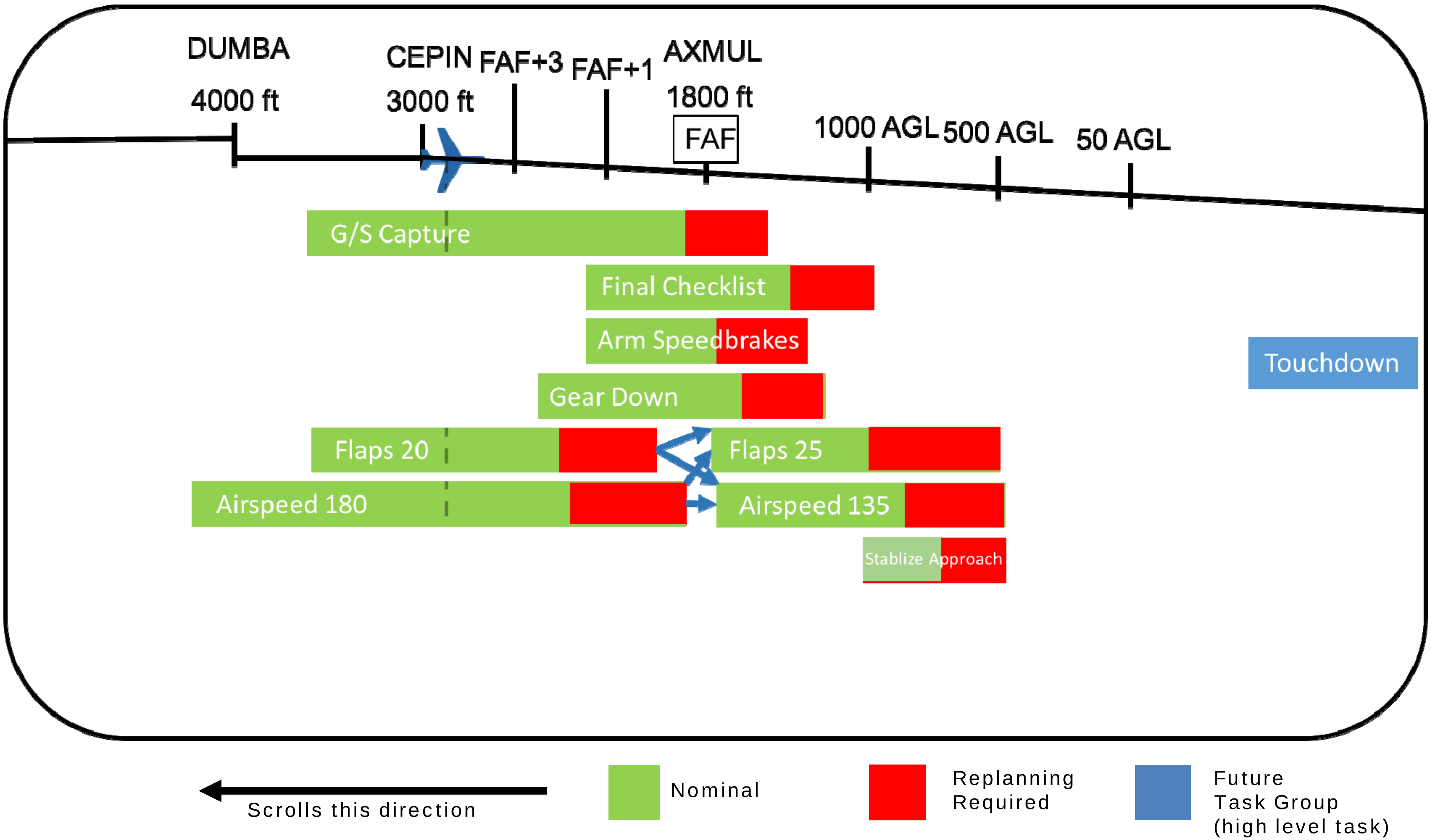
Translate to Hierarchy



Example Activity Plan



Example Activity Plan



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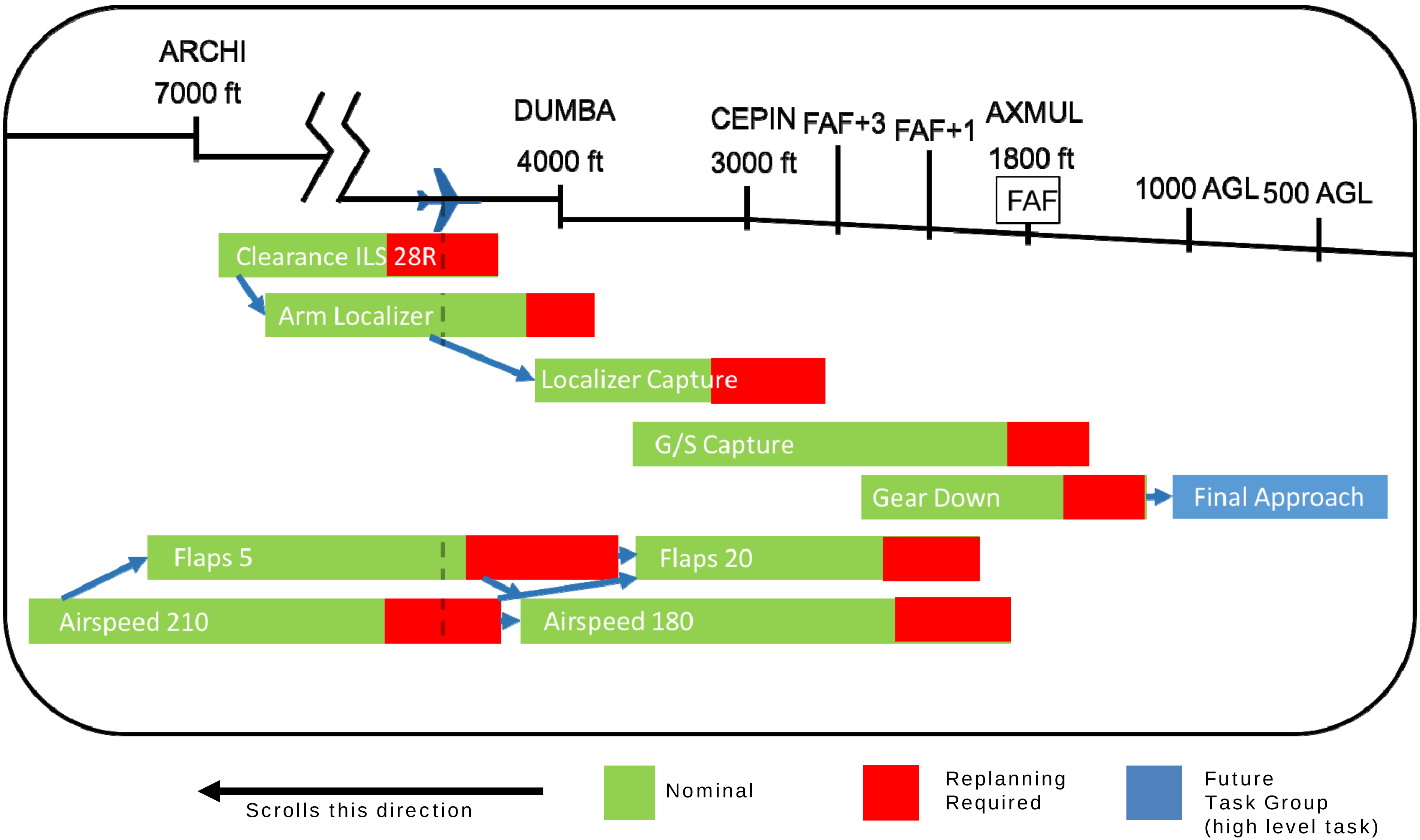

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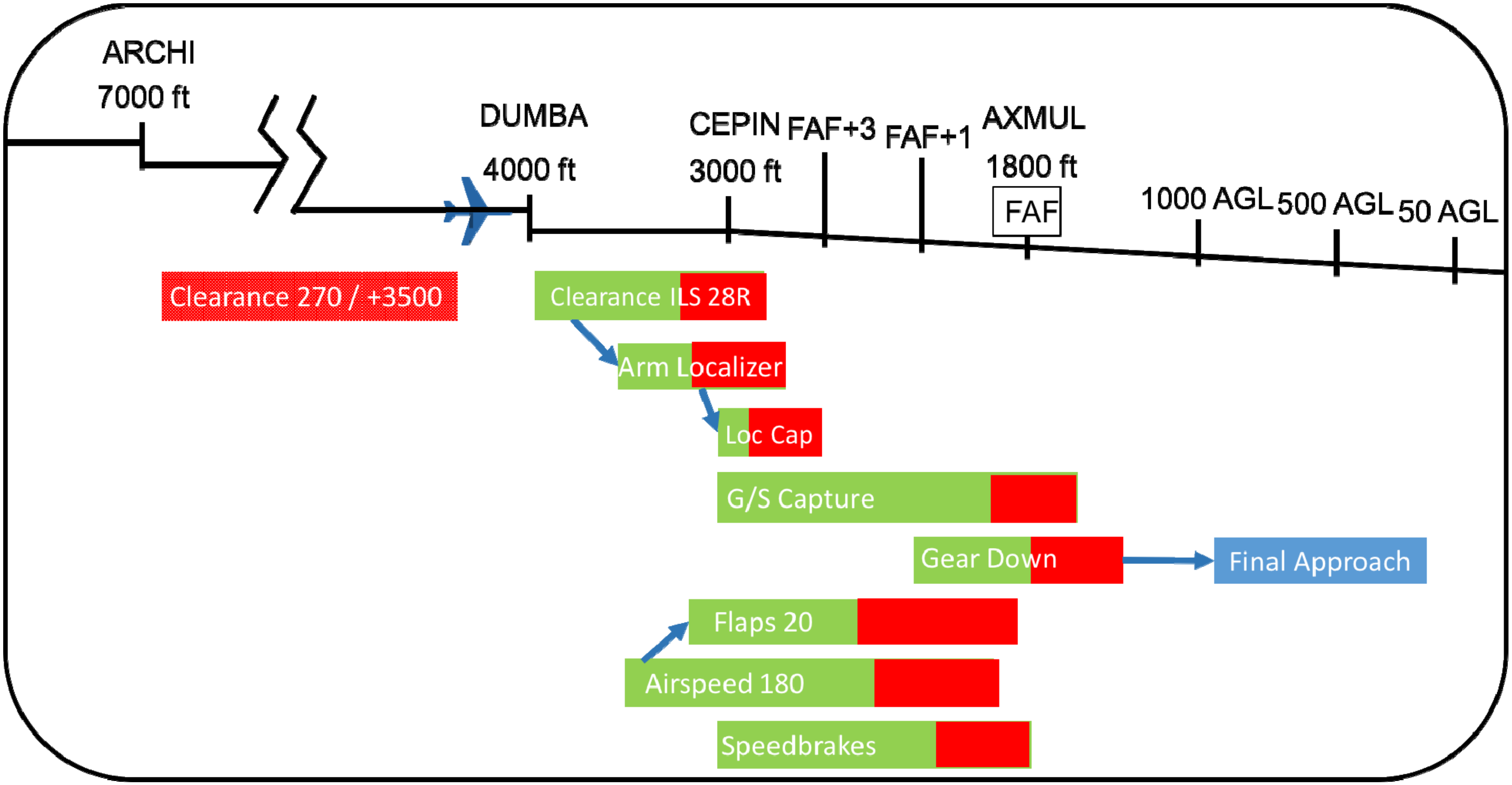


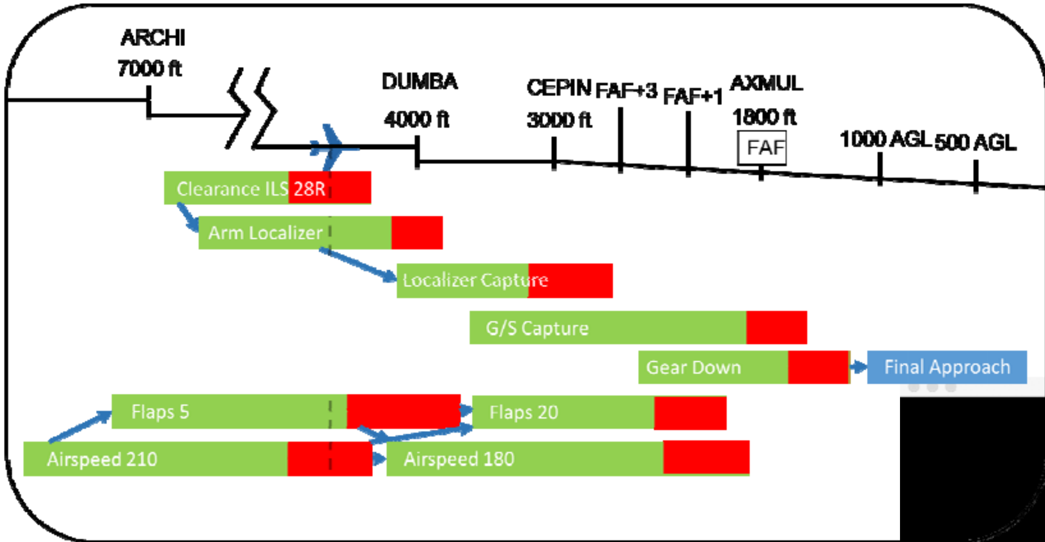
Scrolls this direction

Nominal

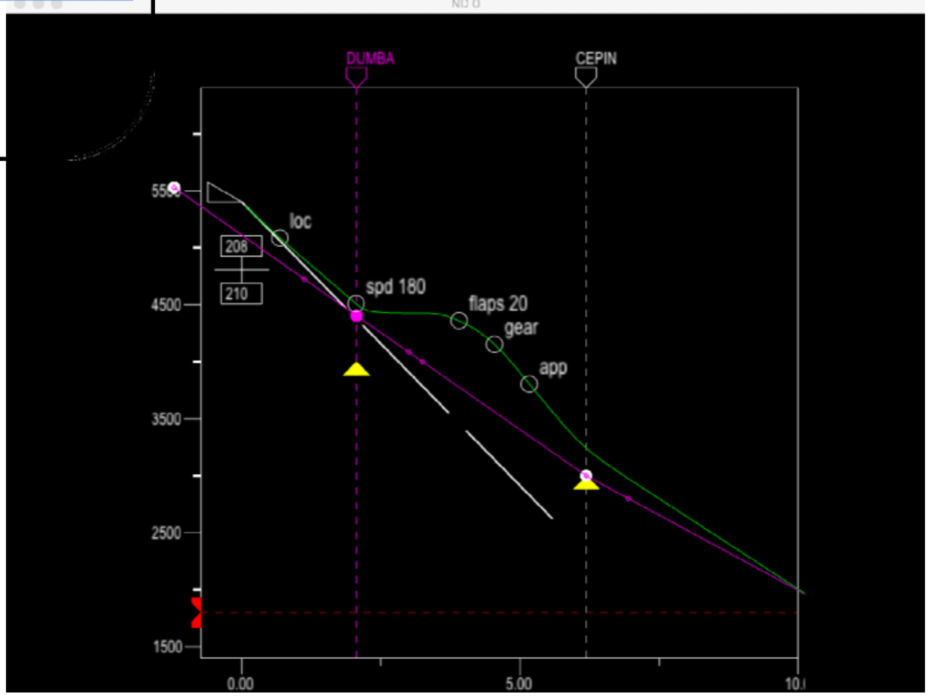
Replanning Required

Future Task Group (high level task)

Projection



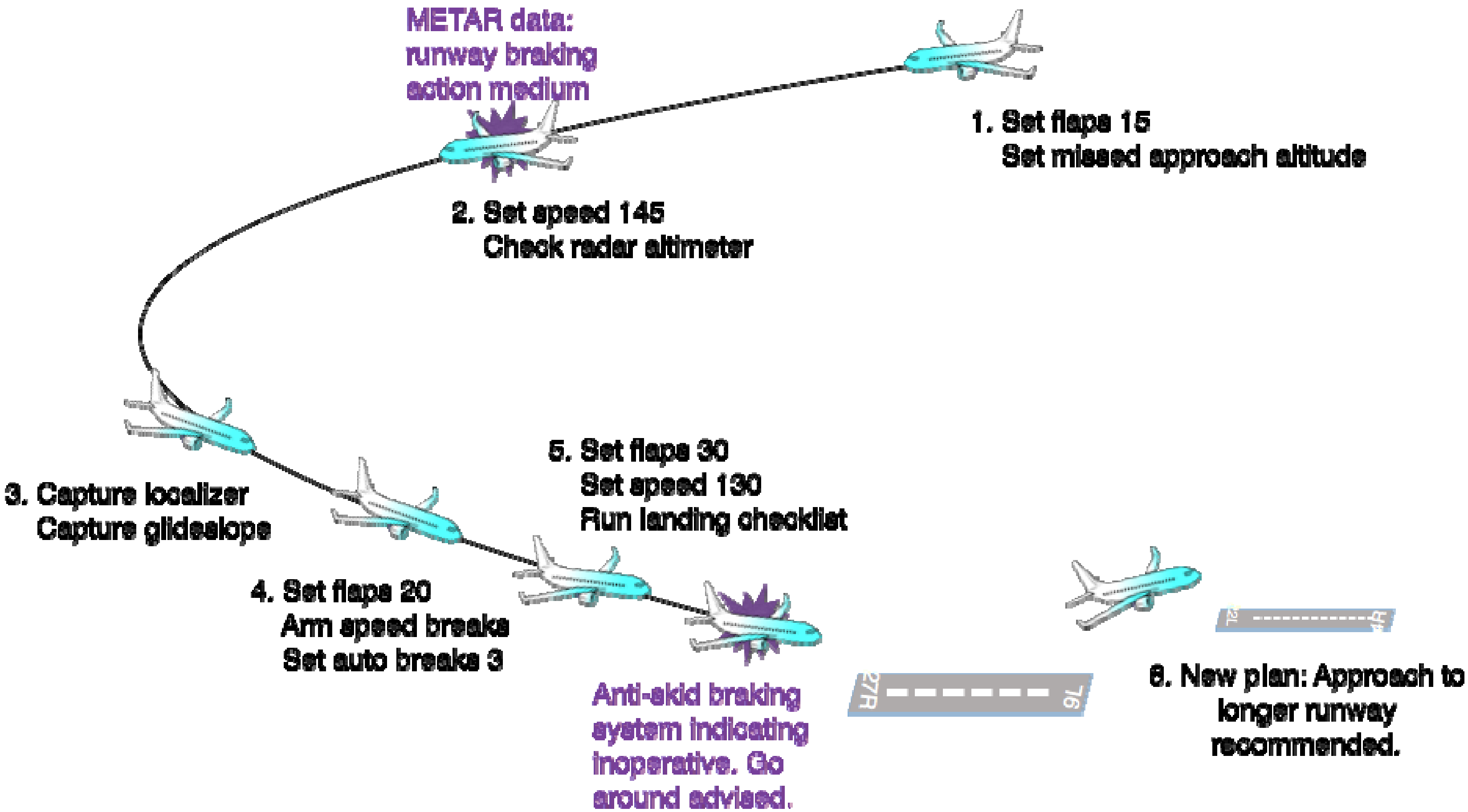
Stochastic Sampling & Local Search



Fast Time Simulation

Monitors and Reaction

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



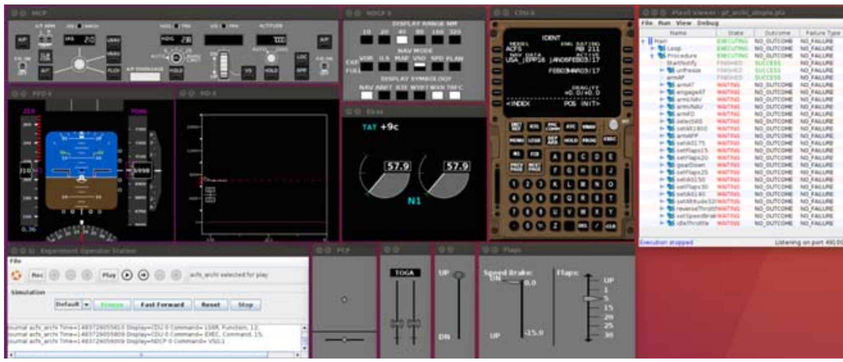
Testing & Integration

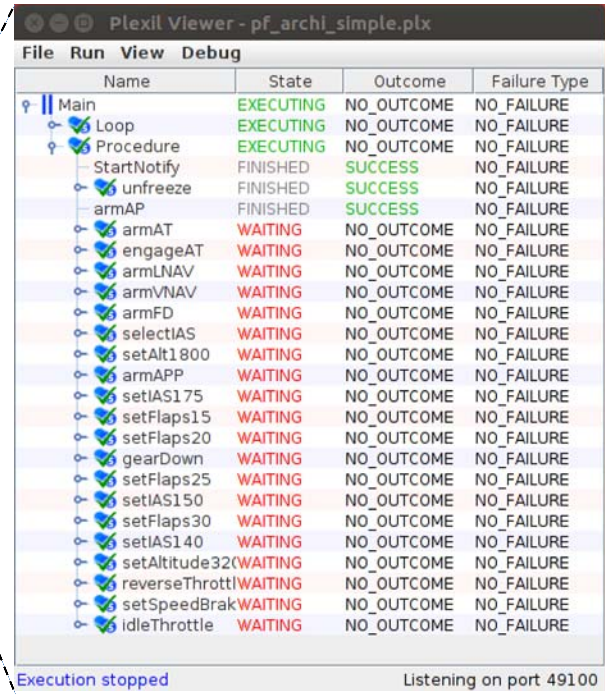
Flight Simulation Integration with PLEXIL

Plan Execution Interchange Language

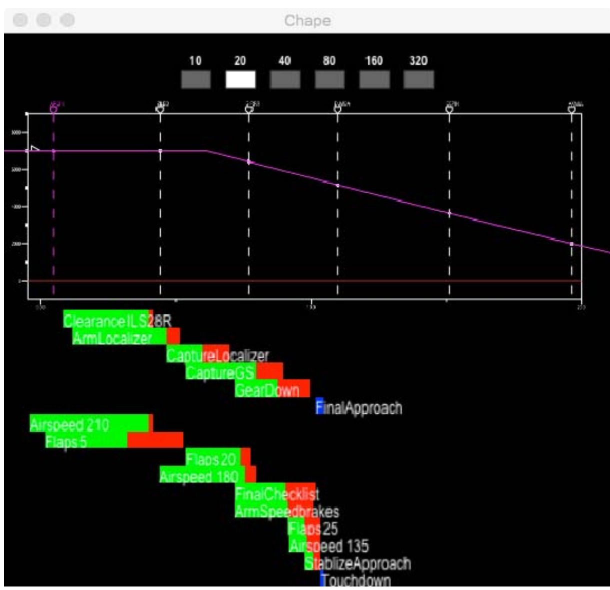
– Instrument monitoring

– Automated flight





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

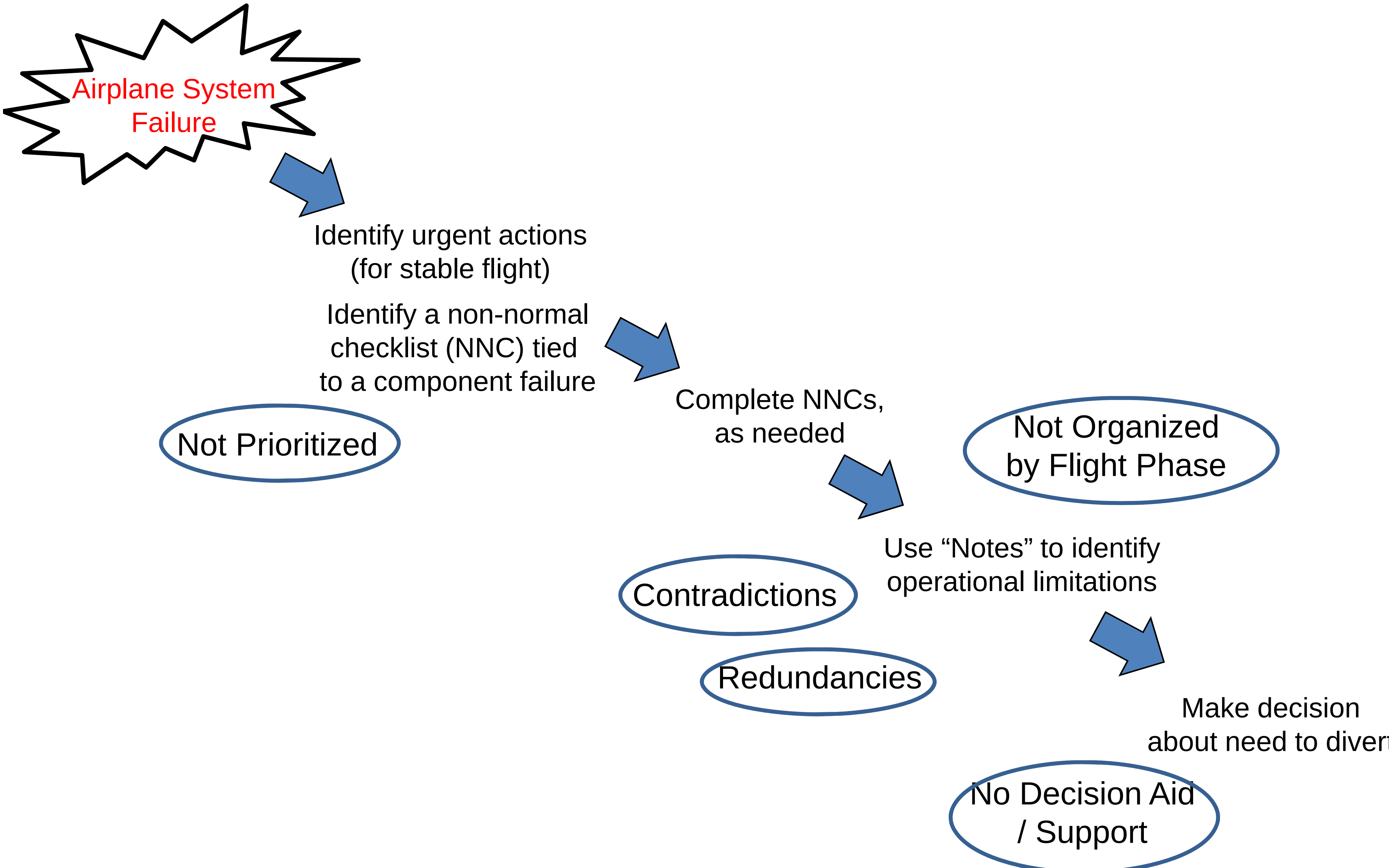
Explosion of Alert Messages

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

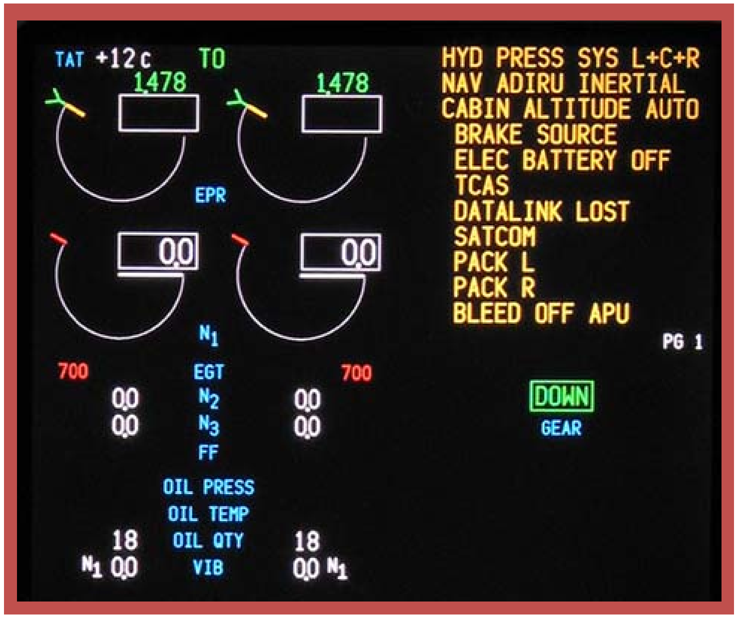
Airplane system components have failed

↓

What can I do?
Where can I go?

Explicit Alerting on Capabilities

Typically, we don't



Can I Fly?

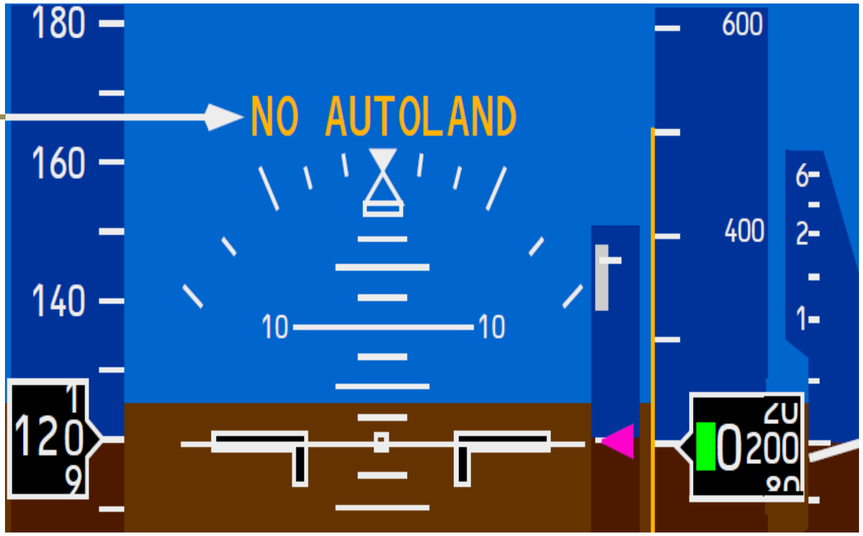
- 787
  - 449 EICAS messages (Warning, Caution, Advisory)
  - All but 19 of them reflect physical system failures/ status changes

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

Airplane System Failure

Time Horizon 1

Identify urgent actions
(for stable flight)

Present an overview of
airplane capabilities
(in addition to EICAS/ECAM)

Goals: reconfigure systems to restore as much capability as possible; understand generally what is possible

Dynamic

Prioritized
NNC selection

Time Horizon 2

Identify operational
limitations
by flight phase

Goals: operate with an understanding of ops limitations for remaining flight; do not “fly into” new problems

Organized by
Phase of Flight

Ability to Look
Ahead for Limitations

Time Horizon 3

Decision Support for
Mission Decision

Goals: understand where you can go and where is “best” to go; look at trade-offs; understand risks

Integrate Airplane
Capabilities with
Airport, Weather,
NOTAMS, etc

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