Cockpit Hierarchical Activity Planning and Execution (CHAP-E)

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Pilot Challenges

- Complex modern cockpits
- Competing goals: dispatch, ATC, pilots themselves
- Dynamically changing situations
  - Aircraft state
  - Weather
  - Changing airport status
  - ATC and dispatch directions
- Loss of situational awareness
- Unclear idea of what to do next
- Incorrect assumptions on automation mode / state
  - Assuming automation will prevent unsafe actions
  - Assuming automation will take necessary actions
The Meat of CHAP-E

- Maintain situational awareness
- Enable automated piloting assistance
- Avoid human error
- Take over flight tasks (on request)
Autonomous Flight & Decision Support

- **Flying**
  - Make critical decisions
    - Awareness of aircraft state
    - Find procedures to follow
    - Decide when to contact ATC
  - Follow flight procedures
    - Decide when to execute steps in procedure
    - Adapt flight procedures for situation

- **Monitoring**
  - Monitor flight situation
    - Check that pilot stays within operational limits
    - Ensure procedures followed
    - Awareness of ATC clearances
  - Monitor flight procedures
    - Monitor procedure compliance
    - Ensure procedures safely carried out
CHAP-E Technologies

- Planning
  - ANML
  - FAPE
  - CHAP-EL
- Fast Simulation
  - TPS
- Execution
  - PLEXIL
Planning – Capture Pilot Procedures

- Standard Operating Procedures
- Carrier Flight Manuals
- Pilot Operating Handbook
- Quick Reference Guides
- Checklists
- Pilot Experience
Planning – Hierarchical Procedures

• Procedures classified into flight phases, clearances and procedures

• During flight, procedures may be modified or added to so that we may maintain flight constraints
Planning – Hierarchical Procedures

• Tasks
  • Primitive
    • Realized actions performed by pilots
  • Non-primitive
    • High-level tasks to perform
    • E.g., approach, set flaps

• 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
Planning – Activity Plan Construction

Translate to Hierarchy
**Scheduling - Procedure Assistance**

- Execution window for each action in a procedure
  - Provide estimates on best time to execute the procedure
    - Earliest Start Time (EST), Latest Start Time (LST), Preferred Earliest Start Time (PEST), Preferred Latest Start Time (PLST), Preferred Start Time (PST)
    - Defines when a pilot should perform tasks, includes exact time point
    - Automated agent performs tasks at Preferred Start Time (PST)
  - Windows found through a combination of domain modeling and fast time simulation (using TPS)

![Diagram showing EST, PEST, PST, PLST, LST and Gear Down]

Displayed
Procedure Execution

“You have to fly before you can monitor.”

Flying:
As long as all the external events happened, do this:

Monitoring:
Is this happening too early or late?
Did the pilots meet the constraints of this procedure?
Is this safe?
Can we still land using this procedure?
Monitoring - Procedure Execution

- Monitor flight constraints
  - Aircraft constraints
    - \( V_{\text{max}} \geq IAS \geq V_{\text{ref}} \)
  - Airline operational constraints
    - Example: Between capturing localizer and the runway, MCP-Lmode should be LOC
    - Example: Stabilized approach between 1000 AGL & runway threshold
- Procedure execution constraints
  - Example: After clearance, and between ARCHI and GIRRR: Arm the localizer
- Trigger re-planning if constraints violated

Events

- before[ARCHI-2] \{ CLR: start(Clearance = ClearedApproach(ILS28R.ARCHI)) \};
- before[ARCHI] \{ F5max: start(IAS <= Vmax5) \};
- F20: start(Flaps = 20);
- A1000: start(Alt <= 1000 + TDZE);

Actions

- after[CLR] & between[ARCHI, GIRRR] \{ ArmLocalizer \};
- after[CLR] & after[F5max] & between[ARCHI, GIRRR] <<SetFlaps(5), SetMCP-SPD(Vref5)>>;
- between[CLR, ARCHI] \{ SetMCP-Alt(1800) \};
- after[F20] & between[AXMUL-2, AXMUL] \{ Gear: SetGear(Down) \};

Monitors

- throughout[CEDES, RW28L] IAS in \[ V_{\text{ref}}, V_{\text{max}} \];
- throughout[LocCap, RW28L] MCP-LMODE = LOC;
- throughout[CEDES, RW28R] \( V_{\text{max}} \geq IAS \geq V_{\text{ref}} \);
- throughout[A1000, RW28R] StabilizedApproach;
Monitoring - Constraint Violations

Procedure Segment:

Before Flaps 20
Airspeed < Vmax20

Flaps 20

Actual Pilot Actions:

Flaps 5 → Airspeed Vref5 → Flaps 20

Flaps 5 → Airspeed Vref5+10 → Flaps 20

Does this violate the procedure?

No: if condition Airspeed < Vmax20 satisfied by Vref5+10
Monitoring - Constraint Violations

Before Flaps 20
Airspeed < Vmax20

Procedure Segment:

Actual Pilot Actions:

Does this violate the procedure?

No: if condition Airspeed < Vmax15 satisfied by Vref5+10
& condition Airspeed < Vmax20 satisfied by Vref15
Monitoring – New External Events

Before Flaps 20
Airspeed < Vmax20

New Clr: Maintain Alt until GIRRR

New Event
Is the procedure still valid?

New Procedure Segment:
(after GIRRR)

Is the procedure still valid?

Procedure Segment:

Before Flaps 20
Airspeed < Vmax20

New Clr: Maintain Alt until GIRRR

Is the procedure still valid?

New Event

New Procedure Segment:
(after GIRRR)
CHAP-E Display
Summary

- Maintains situational awareness
  - Aware of instruments
  - Clearances (data comm)
- Enables automated pilot assistance
  - Suggests procedures based on situation
  - Gives safety margins on procedure execution steps
- Avoids human error
  - Warns prior to missed steps
  - Missed steps will cause procedure re-planning
- Takes over flight tasks
  - Performs suggested procedures
In Progress

• More accurate, detailed modeling of preference windows & constraints

• Continuous Re-scheduling
  • Through fast-simulation, continuously re-schedule - execution windows may shrink, grow, or shift.

• Re-planning
  • Find new procedure when new circumstances occur or current plan is violated

• Improved tolerance of action models to handle common contingencies like speed & altitude restrictions w/out replanning

• Allow pilot to request for automated system to perform certain tasks
Thank you

Art by James Nuanez
• Events
  before[ARCHI-2] {CLR: start(Clearance = {ClearedApproach(ILS28R.ARCHI))}) ;
  before[ARCHI] {F5max: start(IAS <= Vmax5}) ;
  F20: start(Flaps = 20);
  A1000: start[Alt <= 1000 + TDZE) ;
  ...

• Actions
  after[CLR] & between[ARCHI, GIRRR] {ArmLocalizer} ;
  after[CLR] & after[F5max] & between[ARCHI, GIRRR]
    <<SetFlaps(5), SetMCP-SPD(Vref5)>> ;
  between[CLR, ARCHI] {SetMCP-Alt(1800)} ; // glideslope intercept altitude
  after[F20] & between[AXMUL-2, AXMUL] {Gear: SetGear(Down)} ;
  ...

• Monitors
  throughout[CEDES, RW28L] IAS in [Vref,Vmax] ;
  throughout[LocCap, RW28L] MCP-LMODE = LOC ;
  throughout[CEDES, RW28R] Vmax ≥ IAS ≥ Vref ;
  throughout[A1000, RW28R] StabilizedApproach ;
  ...