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16. ABSTRACT
MITRE conducted this human-in-the-loop research project on Interval Management (IM) Controller Pilot Data Link Communications (CPDLC) to investigate the integration of two advanced Next Generation Air Transportation System (NextGen) capabilities across both the air and ground domains to uncover any complications that could arise from two key capabilities that were developed separately. The simulation study included three levels of IM clearance complexity and looked at aircraft equipped only with voice communication capability and those with both voice and CPDLC. An en route air traffic environment was simulated with 50 percent of aircraft equipped with the IM capability. **Results:** Most pilots and controllers in the experiment deemed the IM and CPDLC to be compatible, although the controllers seemed to have more difficulty with mixed IM equipped aircraft than with mixed CPDLC equipped aircraft. Concerns were noted for use of IM with voice communications, since the data entry requirement for the flight crew was increased when CPDLC autoload into the FMS was unavailable. Not surprisingly, this was particularly the case with the most complex IM clearances. **Application:** The results are intended to be used by the FAA as well as EUROCAE and RTCA when developing the technical standards for the interface between the IM and CPDLC equipment. FAA Aviation Safety (AVS) sponsors who develop the regulatory and guidance material for CPDLC and ADS-B are expected to use the results in the development of Advisory Circulars (ACs) and Technical Standard Orders (TSOs) based on the international standards material. Recommendations for consideration by these groups are provided in the Conclusions and Recommendations section of the report.

17. KEY WORDS
data communications; controller-pilot datalink communications; operating limitations; interval management; ADS-B; flight deck procedures; flight management system

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Flight Crew and Air Traffic Controller Interactions when Conducting Interval Management (IM) Utilizing Voice and Controller Pilot Data Link Communications (CPDLC)

Randall Bone
Kevin Long

September 2014

Overview

- Background
- Study Approach
- Flight Deck Interface
- Air Traffic Control (ATC) Interface
- Results
- Key Recommendations
- References
- Abbreviations and Acronyms

Background

Sponsor Organization (at time of simulation)

Human Factors Research and Engineering, ANG-C1

Human Factors Division

- Pauly Krois, Ph.D. Manager ANG-C1
  - **Flight Deck Team**
    - Tom McCloy, Ph.D. Lead
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    - Rachel Seely, Ph.D.
    - Barbara Wilper
  - **Human-System Engineering**
    - Edmundo Sierra
  - **Business Operations**
    - Michelle Whetstine

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Key: (oval) FAA ANG-C1 Sponsors

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Overarching Purpose of Simulation Activity

- **Conduct exploratory research to identify Human Factors issues across Next Generation Air Transportation System (NextGen) capabilities and domains**
- **Examine the interactions between air traffic controllers and flight crews when using a set of defined Controller Pilot Data Link Communications (CPDLC) messages for Interval Management (IM) during Arrival and Approach operations**

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Expected Use of Simulation Results

- **Standards activities in RTCA Special Committee (SC)-186 / EUROCAE (European Organization for Civil Aviation Equipment) Working Group (WG)-51 and RTCA SC-214 / WG-78**
- **Concept as well as CPDLC and voice communications development activities in Surveillance and Broadcast Services (SBS) Program Office**
- **Broader CPDLC questions in Data Communications**
- **Risk reduction associated with NextGen implementation of CPDLC and IM**

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IM Operations Overview

- **Goal: Create operational benefits through management of intervals between aircraft in various environments (e.g., arrival, departure, en route)**
- **IM Operations**
  - Air Traffic Control (ATC) utilizes ground capabilities to manage aircraft streams and to get an aircraft into an appropriate position for the use of Flight deck IM (FIM) capabilities
    - Depending on the operation, new ground tools may or may not be necessary
  - ATC determines aircraft pairs and desired spacing goal
  - ATC transmits target aircraft call sign and IM initiation parameters (e.g., assigned spacing goal, achieve-by point, planned termination point) to IM aircraft
    - An IM turn maneuver may initially be used if speed alone is not sufficient
  - Flight crew of IM aircraft enters the information into FIM system
  - When IM conduct requirements are met, FIM system provides IM speeds for flight crew to fly
  - Flight crew follows the IM speeds and ATC monitors (while maintaining separation responsibility) until termination

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Communication Issues (1 of 2)

- **Current day voice**
  - Issues and errors can increase dramatically when the number of elements* in the communication increase to approximately 3 – 7 (e.g., Cardosi, 1993; Cardosi, Brett, and Han, 1996; Bürki-Cohen, 1995)
  - The communication of navigation fixes in route clearances in the en route environment can be difficult (Prinzo, Hendrix, and Hendrix, 2009)
  - Similar call signs can be confused (e.g., Monan, 1991; Grayson and Billings, 1981; Bürki-Cohen, 1995; Cardosi, Falzarano, and Han, 1999; Canadian Aviation Safety Board, 1990; Van Es, 2004)
- **Future IM Voice**
  - IM clearances can be complex (i.e., have a large number of elements)

* Elements have been defined as "each word, or set of words… [that was] critical to the understanding of the message" (Cardosi, 1993, p. 3)

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Communication Issues (2 of 2)

- **Future IM Voice (continued)**
  - Reference aircraft Intended Flight Path Information (IFPI) can be challenging (Bone, 2014)
    - Unknown waypoints need to be decoded (e.g., after hearing a waypoint like "kēn," knowing that it is spelled K E E E N instead of the numerous other ways it could be spelled)
    - Can be lengthy as it can contain several navigational elements such as waypoints and procedures
  - Third Party Call Sign (TPCS) use can create challenges
    - TPCS use can be an issue for pilots receiving a clearance when the airline telephony designator (e.g., "Brickyard") does not closely match the airline three letter designator (e.g., "RPA") on the traffic display (Bone, 2014)
    - If the reference aircraft flight crew overhears their call sign used on the frequency, they may think the communication is for them. This could lead to them querying ATC, which results in extra transmissions and use of valuable frequency time
      - They could also possibly not ask but instead accept an instruction or clearance that was intended for another aircraft

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CPDLC Overview

- Air – ground data link text message capability
- ATC utilizes CPDLC to send messages such as clearances and instructions
- Flight crews utilize CPDLC to reply to ATC messages or send messages such as requests
- Both ATC and flight crews have new capabilities to support the exchange of CPDLC messages
- Messages can either be pre-defined and formatted or free text
- Messages can be individual elements (one specific communication) or concatenated elements (two or more combined specific communications)
- Required Communication Performance (RCP) "defines a performance standard for operational communication transactions. Each RCP type denotes values for communication transaction time, continuity, availability and integrity," International Civil Aviation Organization (ICAO), 2008

IM CPDLC Union

- **Data link is believed to be an improvement for certain IM application communications and may be required for more complex IM application communications**
  - "Controllers found great [benefits] with data link, concerning safety and workload." (Nyberg, 2006)
  - "The evaluation of the use of datalink for [IM] procedures instead of [voice] was recommended by controllers." (Hassa, Haugg, and Udovic, 2005)
- **IM CPDLC message underwent development in RTCA SC-214 / EUROCAE WG-78**

Past IM Voice and CPDLC IM Clearance Complexities

- **Voice**
  - 4 – 7 elements was typical (e.g., e.g., Mercer et al., 2005; Hassa, Haugg, and Udovic, 2005)
- **CPDLC with manual load**
  - 6 elements (Nyberg, 2006)
- **CPDLC with direct load**
  - 9 and 27 elements (Prevot et al., 2007; Baxley et al., 2013)

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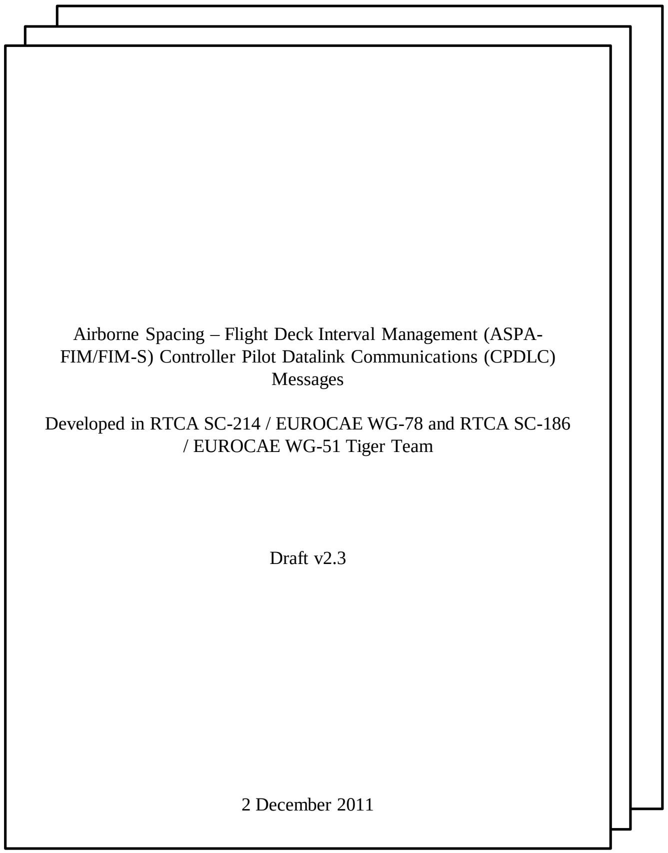
Study Approach

Specific Objectives

- **Examine**
  - Message set
  - RCP
  - Pilot and controller procedures
  - Interface issues

Examine Message Set (1 of 3)


Airborne Spacing – Flight Deck Interval Management (ASPA-FIM/FIM-S) Controller Pilot Datalink Communications (CPDLC) Messages

Developed in RTCA SC-214 / EUROCAE WG-78 and RTCA SC-186 / EUROCAE WG-51 Tiger Team

Draft v2.3

2 December 2011

- ***"Airborne Spacing – Flight Deck Interval Management (ASPA-FIM / FIM-S) Controller Pilot Data Link Communications (CPDLC) Messages"***
- **RTCA SC-214 / EUROCAE WG-78 and RTCA SC-186 / EUROCAE WG-51 Tiger Team**
- **Defined uplink messages and downlink messages for use during IM operations**

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Examine Message Set (2 of 3)

- **Questions**
  - Are the CPDLC messages defined for IM the necessary messages for both pilots and controllers?
  - Are pilots and controllers able to understand and communicate effectively with these messages?
    - Are the structure and content of the CPDLC messages appropriate for IM?
  - Are other messages needed?
  - What limitations are there with voice communications for IM which will necessitate CPDLC?
- **Method**
  - Compare CPDLC with baseline voice condition
  - Vary levels of complexity of the IM clearance
    - Lower, Moderate, and Higher

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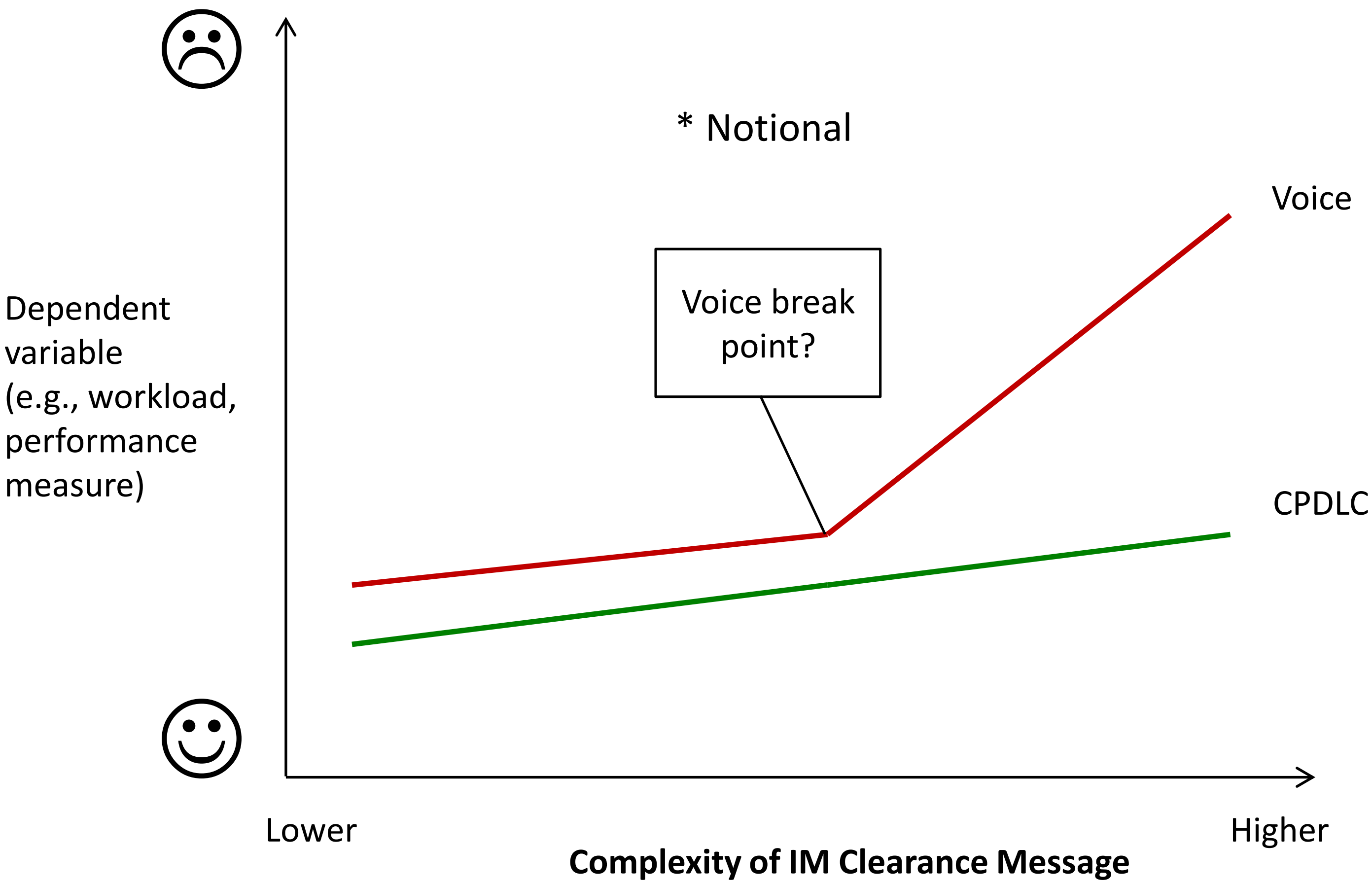
Examine Message Set (3 of 3)

At what level of IM clearance complexity does voice communications become too difficult?



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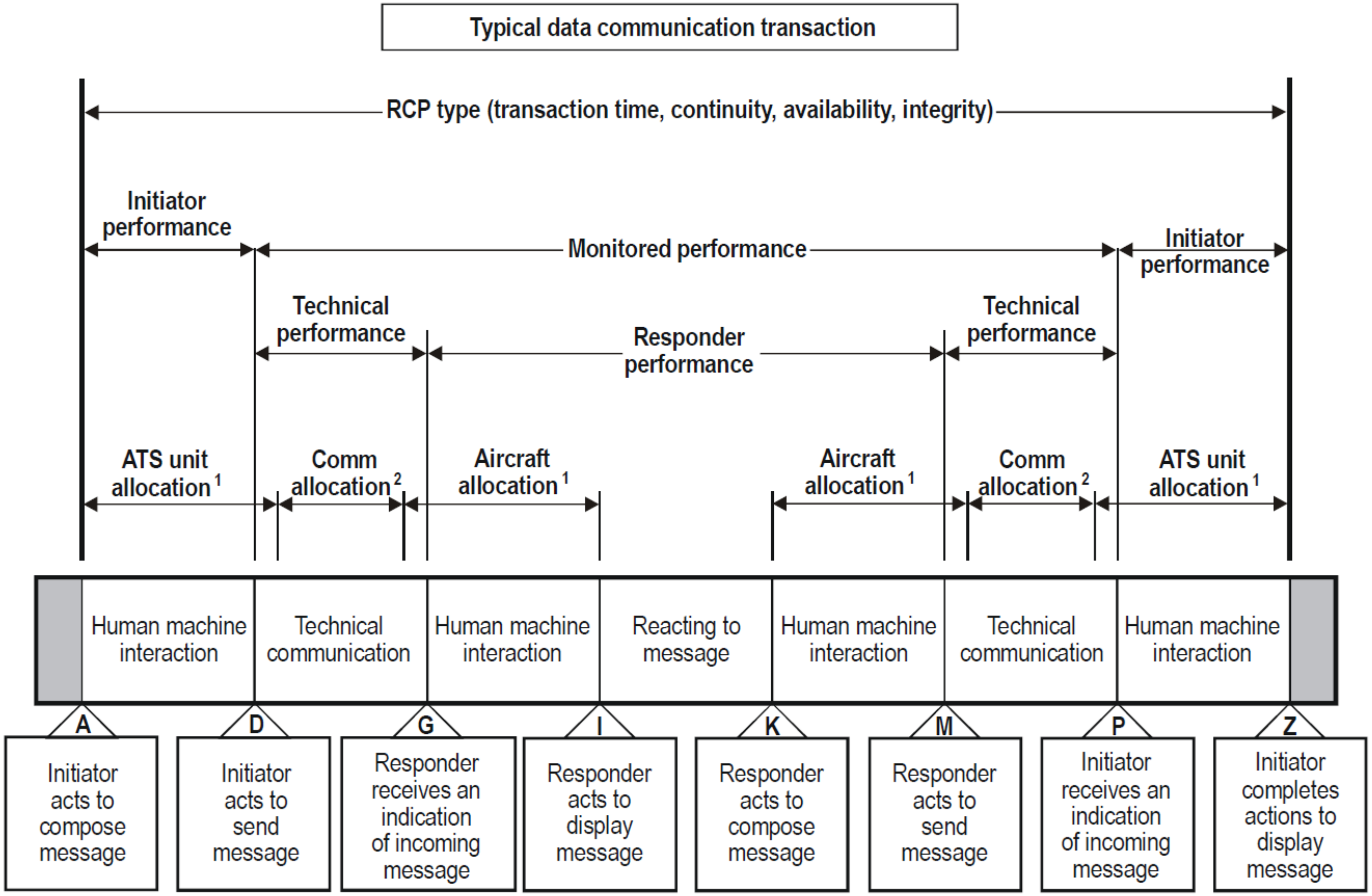
Examine RCP (1 of 2)



Note 1.— A controller-initiated transaction is shown. ATS unit and aircraft allocations are transposed for a pilot-initiated transaction.
Note 2.— The aircraft and ATS unit allocations include HMI and a portion of the technical communication to provide a basis for the different types of approvals.

(ICAO, 2008)

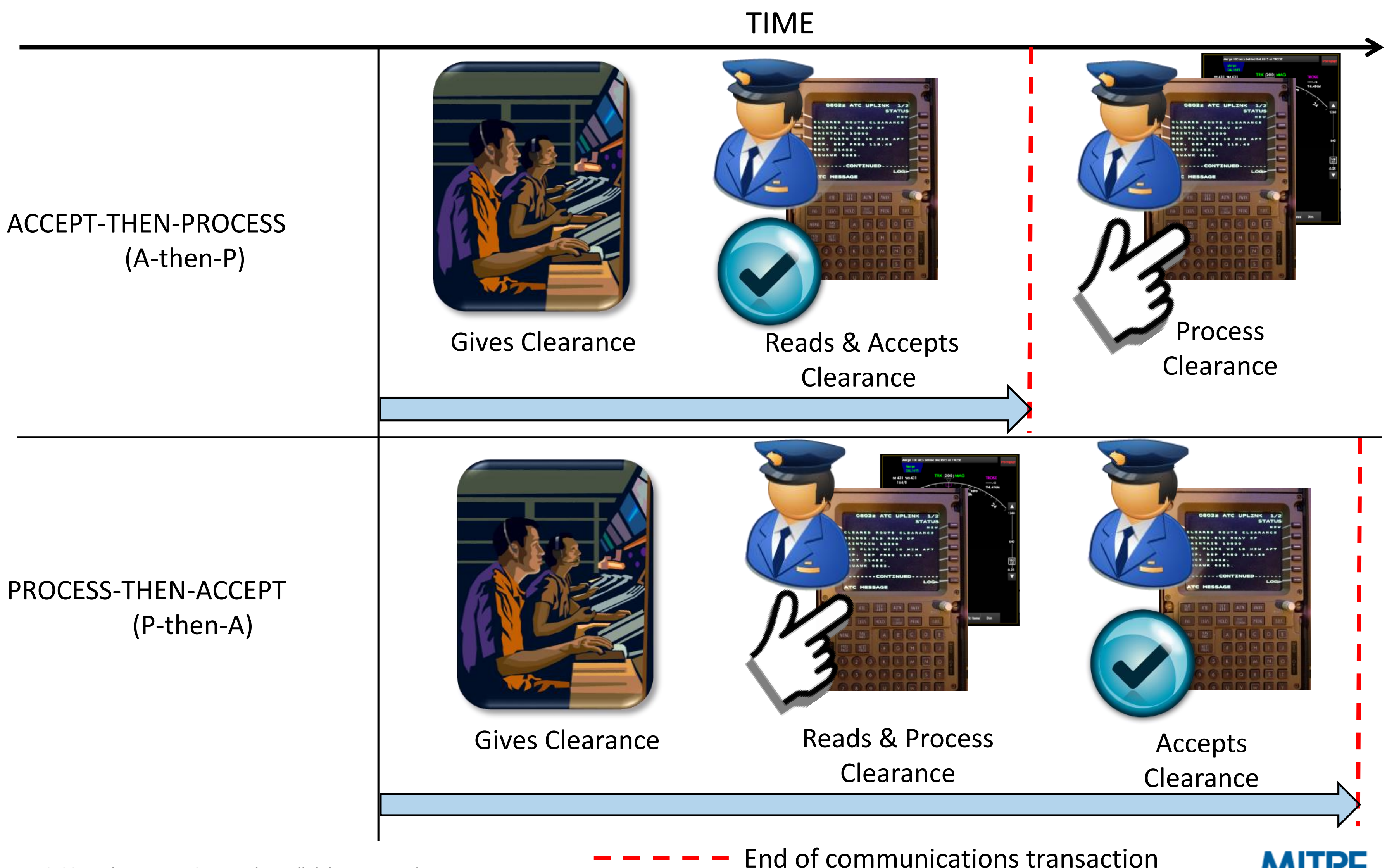
ATS – Air Traffic Services
HMI – Human Machine Interaction

Examine RCP (2 of 2)

- **Questions**
  - Is the RCP of 180 seconds (as defined at the time of the simulation*) adequate for flight crews under the scenarios being investigated?
    - How long do pilots take to receive, execute, and respond to IM messages?
  - Given that a controller may not receive a pilot response to a clearance in a timely manner, what is the impact on controller situation awareness and workload?
- **Method**
  - Measure pilot response time from the time the message is received on the flight deck to the time they provide a response (Standby, Accept, or Reject)
  - Measure controller workload, comparing workload during voice baseline versus CPDLC
  - Measure pilot and controller acceptability

* At the time of the simulation development, RCP180 was derived for IM. However, after completion of the simulation, RCP180 was no longer specified. RCP130 was the next closest RCP type and was chosen for IM (RTCA and EUROCAE, 2014).

Examine Controller and Pilot Procedures (1 of 2)



Examine Controller and Pilot Procedures (2 of 2)

- **Questions**
  - Should the flight crew procedure be "P-then-A" or "(reasonable check) A-then-P"?
  - What is the impact of an A-then-P procedure on controller workload?
  - Can the flight crew and controller transition easily to voice in a non-normal situation?
- **Method**
  - Develop and use A-then-P procedures, assess pilot acceptability and controller workload

Examine Interface Issues (1 of 2)

- **Questions**
  - Can the flight crew and controller perform his / her task safely and efficiently with the specified interface?
    - There are 2 aspects of interface to consider
      - System type
        - Flight crew: how does the flight crew interact with CPDLC messages, through the Multifunction Control and Display Unit (MCDU) or through a dedicated large display format?
        - En route controller: how does the en route controller interact with CPDLC messages and the IM system?
      - Generation and loading of IM communications for both ground and flight crew
        - Auto generated or manually generated by the controller
        - Loadable directly or manually into FIM equipment by the flight crew

Examine Interface Issues (2 of 2)

- **Method**
  – Decide on specific interfaces for both controller and flight crew and assess their utility in terms of task performance and workload

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Assumptions

- **Equipage environment**
  - 50% aircraft in simulation are IM capable
  - 50% aircraft in simulation are CPDLC capable
- **Flight deck test crew**
  - Always IM capable and CPDLC capable (for scenarios with CPDLC)
  - CPDLC through Boeing 737-like MCDU interface
  - Cockpit Display of Traffic Information (CDTI) hosted on side display
- **En route controller test participant**
  - Radar-side controller performs all tasks
  - Ground-based Interval Management (GIM) spacing list from MITRE 2011 study will be used (Peterson, Penhallegon, and Moertl, 2012)
  - Display System Integration (DSI) will be used
  - CPDLC message is automatically generated for controller, controller checks, and then sends message

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Test Variables

ATC

Communication Method	IM Clearance Complexity
Voice (100%)	Lower
	Moderate
	Higher
CPDLC (50%) and Voice (50%)	Lower
	Moderate
	Higher

Flight Crew

Communication Method	IM Clearance Complexity
Voice with Manual Load	Lower
	Moderate
	Higher
CPDLC with Manual Load	Lower
	Moderate
	Higher
CPDLC with Direct Load	Lower
	Moderate
	Higher

Test Design

Each scenario ~40 minutes each

Two runs within each ~40 minute scenario

		ATC		Flight Crew
Voice	1	Lower complexity IM Clearance	R1	Lower complexity IM Clearance
			R2	Lower complexity IM Clearance
	2	Moderate complexity IM Clearance	R3	Moderate complexity IM Clearance
			R4	Moderate complexity IM Clearance
	3	Higher complexity IM Clearance	R5	Higher complexity IM Clearance
			R6	Higher complexity IM Clearance
CPDLC (50%) and Voice (50%)	4	Lower complexity IM Clearance	R7	Lower complexity IM Clearance – direct load
			R8	Lower complexity IM Clearance – manual
	5	Moderate complexity IM Clearance	R9	Moderate complexity IM Clearance – direct load
			R10	Moderate complexity IM Clearance – manual
	6	Higher complexity IM Clearance	R11	Higher complexity IM Clearance – direct load
			R12	Higher complexity IM Clearance – manual

Plus an extra scenario examining additional IM messages (e.g., pilot termination, controller termination)

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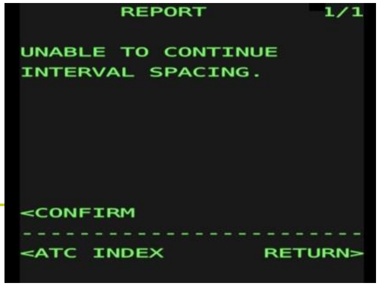
Test Design – Extra Scenario (#7)



- **Developed "outside" the counterbalanced design that focused on the IM Clearance**
- **Developed to receive feedback on additional IM messages not utilized in other scenarios**
  - **ATC clearance with "when able…report starting spacing"** – "When able, for interval spacing, cross KEEEN 120 seconds behind United 123, merging at KEEEN. Report starting interval spacing."
    - Flight crew reply – "Interval spacing behind United 123"
  - **ATC request to report ASG** – "Report assigned spacing interval behind United 123."
    - **Flight crew reply** – "Assigned spacing interval 120 seconds behind United 123"
  - **ATC termination** - "Cancel interval spacing."
  - **Flight crew termination** – "Unable to continue interval spacing"

Typical Scenario

- ATC managed several aircraft conducting IM via CPDLC or voice communications over an approximately 40-minute scenario
- Flight crew acted as IM participant and flew IM until termination point (at or before terminal airspace). Afterward, the flight crew “jumped” to a new position outside the sector and then flew into the sector to perform another IM operation
- Pseudo-pilots “flew” other aircraft within the simulation. These aircraft performed IM operations and other flight maneuvers as directed by ATC

Participants

- **ATC Participants**
  - 10 current en route controllers
  - Average 17 years of ATC experience
- **Pilot Participants**
  - 10 professional flight crews (20 pilots), experienced with Boeing glass cockpits with Electronic Flight Instrument System (EFIS) and MCDU operation
  - Average of 13,348 hours total flight time
- **Simulation Staff**
  - Observers, Director, and Trainers
  - Pseudo-pilot
    - Data was **not** collected directly from pseudo-pilots on IM or CPDLC
    - Data was collected from ATC, based on their interactions with pseudo-pilots during IM and CPDLC operations

Simulation Environment (1 of 2)

En Route ATC

En Route Voice or CPDLC Frequency

Flight Crew

Pseudo-pilot

Simulation Environment (2 of 2)

- DSI
- CPDLC functionality
- GIM functionality providing recommended IM initiation parameters

- CPDLC functionality within MCDU
- FIM functionality on side CDTI traffic display

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Test Procedures

- **Two days per participant set (2 pilots and 1 en route controller)**
  - All participants remained together as a “group” throughout the 2-day training / test session
- **Training and familiarization (Day 1 morning)**
  - Consent form
  - Introductory concept briefing
  - Training sessions in lab
    - Training scenarios covered all events in data collection scenarios
  - Data collection scenarios
- **Data Collection Scenarios (Day 1 afternoon & Day 2)**
  - Counterbalanced order of scenarios
  - Scripted errors / readbacks from pseudo-pilots
- **Debrief (Day 2)**
  - Questionnaires and discussion

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Flight Deck Interface

CPDLC Interface

- **CPDLC received through the MCDU**
  - Similar to a Boeing 737 implementation
  - Selected as it presents a relatively more difficult data communications interface compared to other implementations (e.g., Boeing 777 or Boeing 787)
  - Allows collection of pilot response time data to assess RCP with a relatively more difficult interface implementation

- **Interface Development Method**
  - Consulted pilot subject matter experts involved in RTCA SC-214 / EUROCAE WG-78
  - Followed, in general, design principles seen with Boeing 737 CPDLC interface on the MCDU

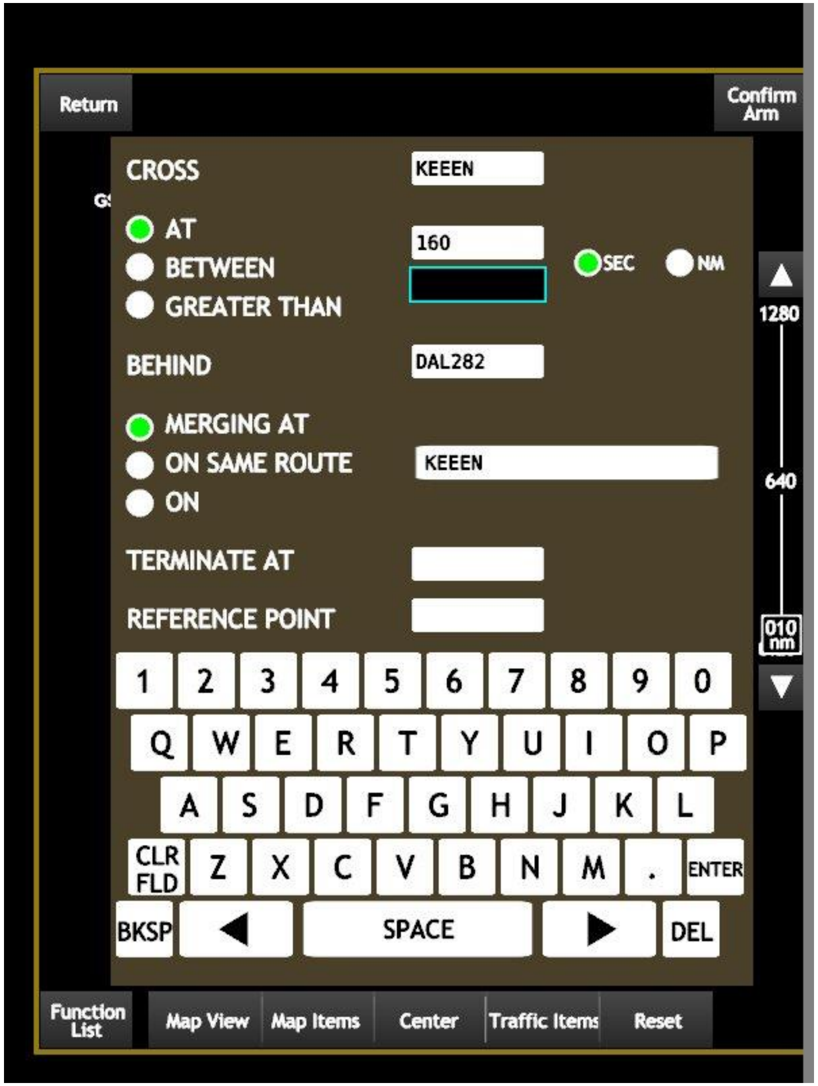
CPDLC Interface

IM Interface

- **The two main displays that the flight crew used to execute and monitor IM operations were:**
  - CDTI
    - Traffic display
    - IM window to enter elements of the IM clearance
      - Elements are either manually entered or loaded directly from the MCDU
  - Auxiliary Guidance Display (AGD)

- **Method**
  - Displays were designed based on an understanding of the operational needs of pilots in executing IM
  - The CDTI has been used in previous human-in-the-loop (HITL) simulations
  - The IM window allows entry of the clearance elements and was designed to follow the phraseology of IM clearances

IM Interface – IM Window



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IM Interface – CDTI Traffic Display

Operation Identification

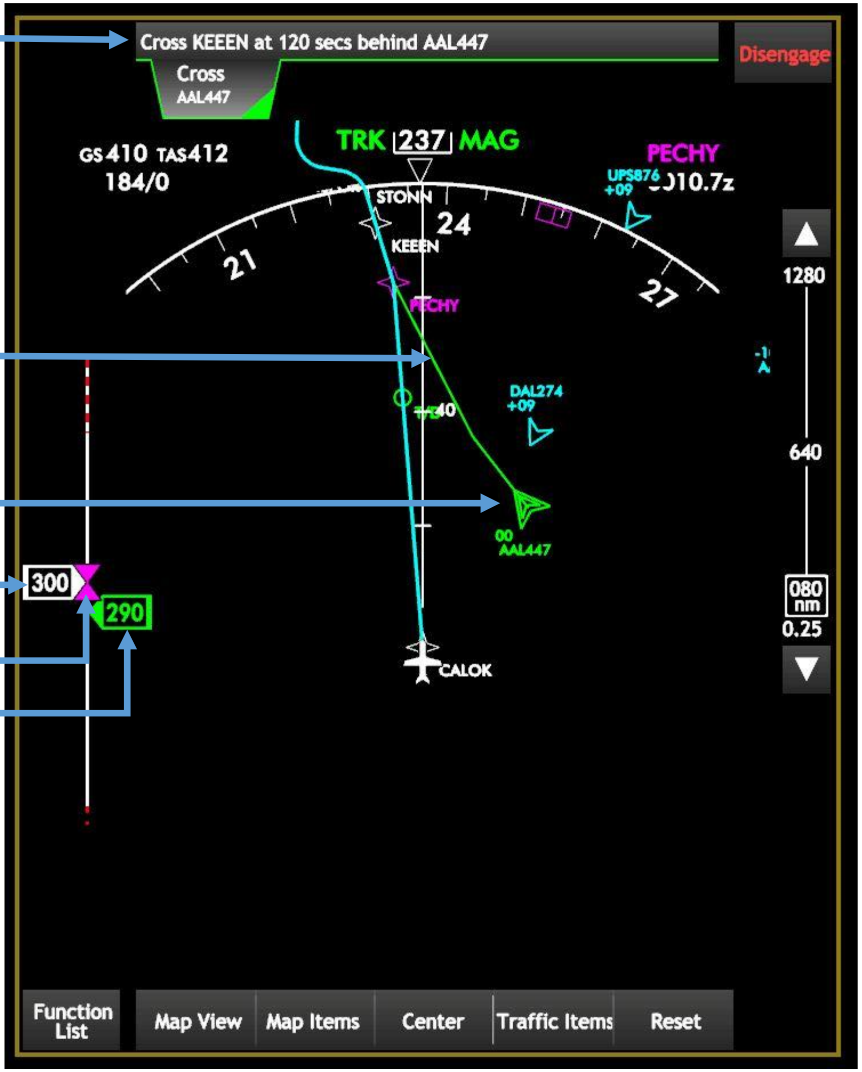
Designated Aircraft Flight Path

Designated Aircraft

Current Indicated Air Speed (IAS)

MCP Speed

IM Speed



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IM Interface – AGD

The AGD was a supplemental display that provided the key information for the operation in the pilots forward field of view

IM speed

Target Aircraft identification

Current In-Trail Time

Assigned Spacing Goal

HDG – Heading
ITT – In-Trail Time
S – Seconds

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ATC Interface

Design Approach (1 of 2)

- **The goal was to develop an interface for CPDLC for the en route controller for the purposes of accomplishing the objectives of the simulation**
- **The interface developed for the simulation is one example of a suitable interface and MITRE is not prescribing this to be the only interface possible**
- **Method**
  - Consulted existing sources:
    - "Data Communications Human-In-The-Loop Simulator Draft Thinspec" (FAA, 2010)
    - "Conceptual Use Case: Arrival Interval Management – Spacing (IM-S) and Ground based Interval Management for Spacing (GIM-S)" (National User Team FAA ATO ERAM, 2012)

ERAM – En Route Automation Modernization

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Design Approach (2 of 2)

- **Method (continued)**
  - Inferred design and interaction philosophies from sources and any lessons learned from previous MITRE GIM HITLs
  - Assumed a non-exhaustive set of operational requirements that must be met by the design elements of the interface
  - Developed design requirements that would support the assumed operational requirements

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Design and Interaction Guidelines

- **Direct graphical interaction with aircraft data block that will receive CPDLC instructions / clearances**
  - Invoke communications by clicking on specific element on flight data block, e.g., click on speed if controller wants to send a speed clearance
- **Provide CPDLC capability and message status indications within data block**

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Assumed Basic CPDLC-GIM Operational Requirements (not an exhaustive list)

- **The controller shall be:**
  - Able to tell which aircraft are capable of CPDLC and IM operations
  - Able to view the actual message before it is sent
  - Aware of the state of the communications transaction – message sent, message accepted, message rejected, or standby
  - Able to view a history of CPDLC communications, including the messages sent, recipient aircraft, and the state of the communications
- **IM clearances shall be automatically constructed for the controller based on recommendations from GIM**

Overview of ATC Interface

- **The main interfaces that the controller interacted with included:**
  - Aircraft Data Block
  - GIM Spacing List
  - Clearance Template

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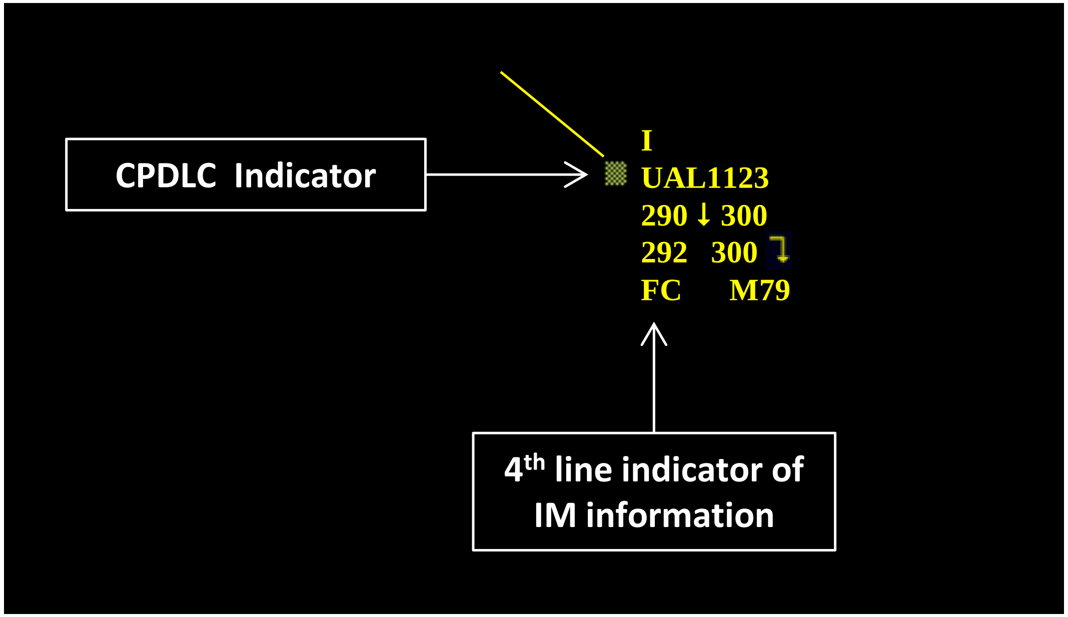
Aircraft Data Block



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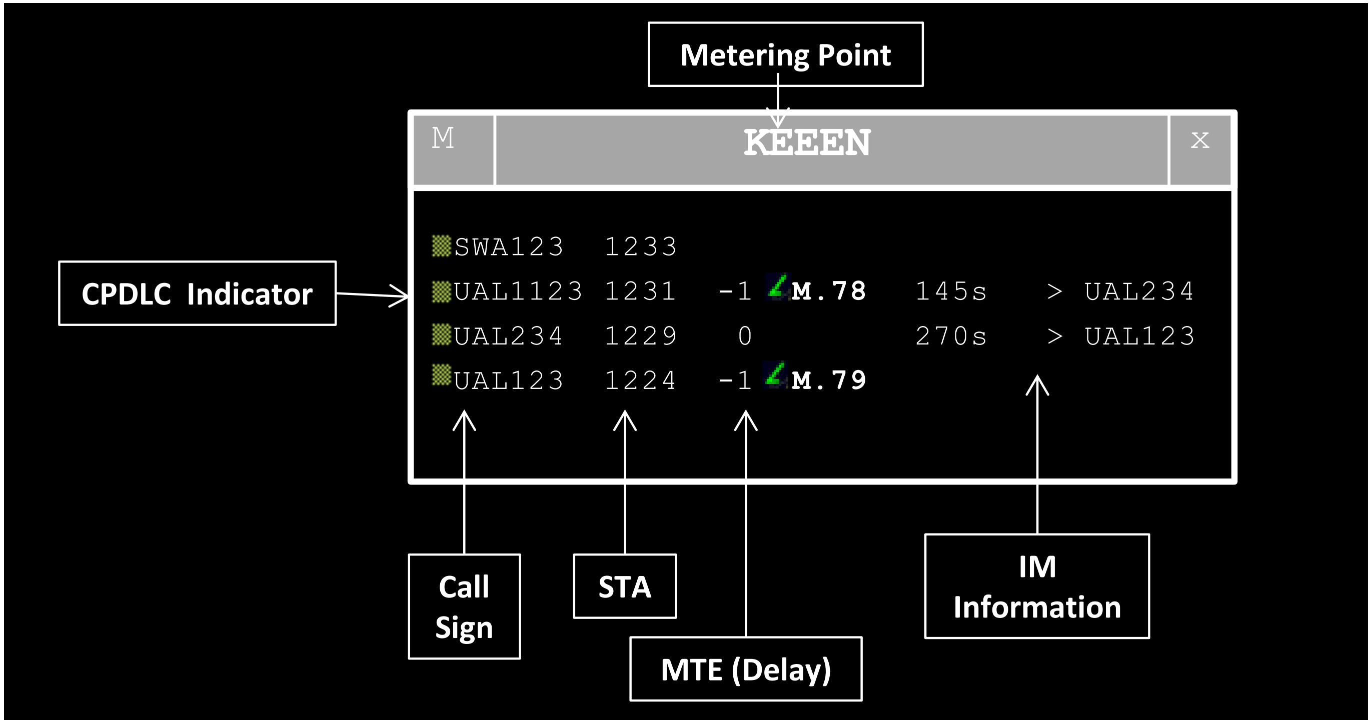
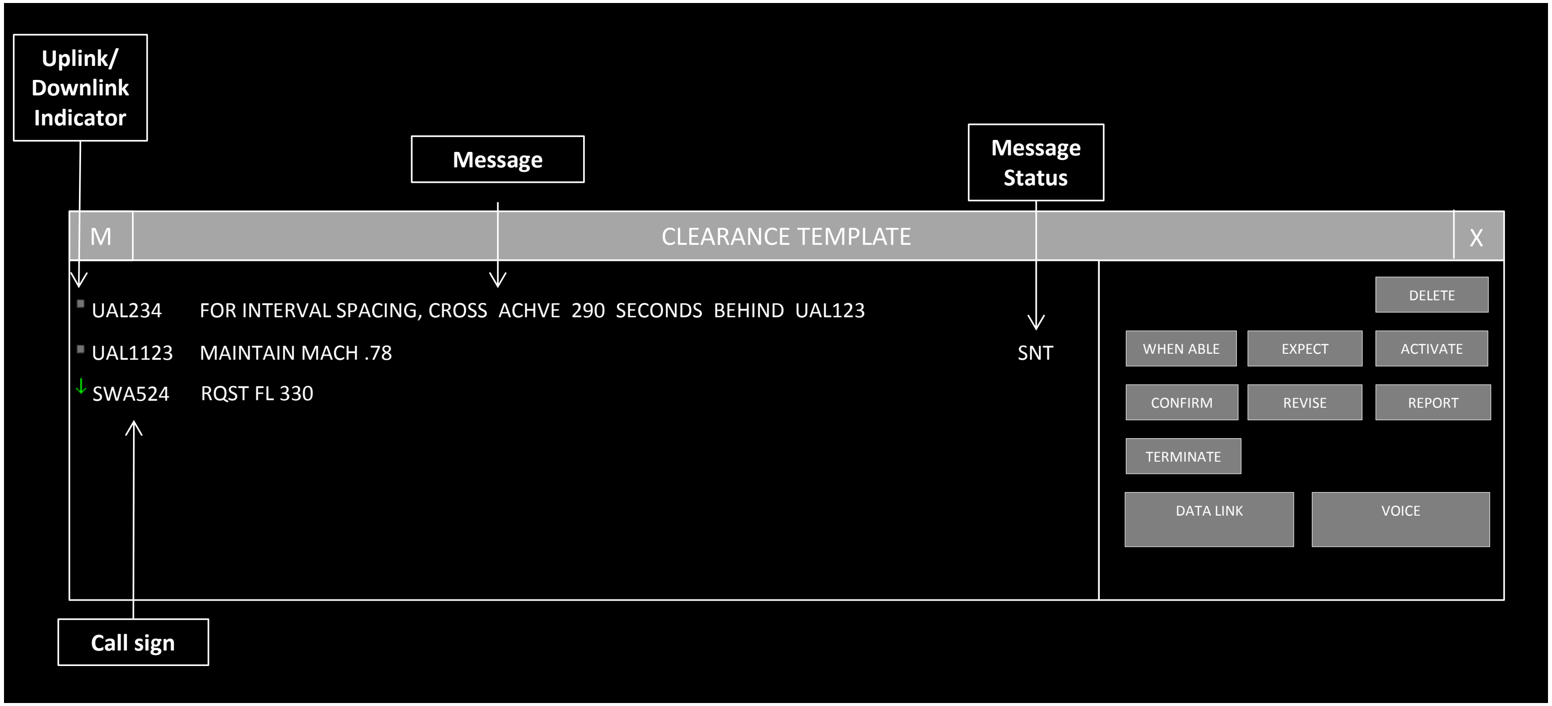
GIM Spacing List



MTE – Meet Time Error
STA – Scheduled Time of Arrival
s – Seconds

Clearance Template



FL – Flight Level
RQST – Request
SNT – Sent

Results

IM and CPDLC (1 of 2)

- **Vast majority of controllers and pilots agreed that IM is operationally acceptable**
  - While the controllers found the concept acceptable, the majority did report issues with conducting IM in a mixed (50%) IM equipage environment
    - Controller comments were related to time on frequency for IM clearances, mix of IM and non-IM operations, and applicability to more complex environments
- **Vast majority of pilots and controllers reported they preferred using CPDLC for the complex IM clearances**
  - In addition, all non-IM CPDLC messages were reported to be acceptable

IM and CPDLC (2 of 2)

- **For controllers, mixed CPDLC equipage (50%) appeared to be less of an issue than it was for mixed IM equipage**
- **While preferring CPDLC, both controllers and pilots reported wanting to revert, and actually reverting, to voice communication for certain communications**
  - Pilot feedback on reversions to voice were often for termination of IM or to get clarification on the reference aircraft IFPI or IM procedures
  - Controller feedback on reversions to voice were for time critical messages such as the instruction to cancel the IM clearance

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Communications – General

- **More communication issues when using voice as compared to when using CPDLC**
  - Many more communication issues when conveying the Higher complexity IM clearance over voice communications
  - Pilot reported less follow-on communications with CPDLC than with voice
- **CPDLC reduced the amount of time both controllers and pilots spend on the voice frequency**
- **When pilots were using voice communications for the Higher complexity IM clearances, they spent significantly more time on the voice frequency relative to the other conditions**
- **Most controller and pilot responses indicated general acceptability of TPCS use**
  - Most problems were related to the "airline telephony designator" spoken in the voice communication not matching the "airline three letter designator" shown on the CDTI traffic display

Communications – IM Clearance (1 of 2)

- **Pilots:**
  - Showed acceptability of all conditions even though there were differences found among the conditions
  - Consistently showed a preference for the Lower and Moderate complexity IM clearances as compared to the Higher complexity IM clearances
  - Consistently showed a preference for CPDLC with Manual Load and CPDLC with Direct Load over Voice with Manual Load
  - Consistently found the least favorable set of conditions to be Higher complexity IM clearances when using Voice with Manual Load

Communications – IM Clearance (2 of 2)

- **Controllers:**
  - Had higher variability in their responses
    - Most variability in replies appears to have been with the Higher Complexity IM clearances under both Voice and CPDLC
  - Preferred CPDLC over voice communications although it seemed to be less of a factor when considering questions on the IM clearance

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Communications – Other IM Messages

- **Messages appear to be well phrased and allow for acceptable and clear communication exchanges in both voice and CPDLC**
- **Pilots and controllers did not identify the need for any additional messages under the conditions simulated**
- **Main comments related to these messages were about termination messages and were more about procedures versus the messages themselves**
  - Both pilots and controllers reported that termination is likely best done over voice communications due to the delay in CPDLC
  - Pilots also reported that they were unsure whether the controller received their “unable” (termination) message. Pilots wanted clearer acknowledgement from the controllers upon receipt of the “unable” (termination) message.

Communication Transaction Times and RCP

- **Vast majority of times associated with CPDLC communications aligned with RCP130 requirements ***
- **Both CPDLC with Manual Load and CPDLC with Direct Load had faster pilot performance times than the Voice with Manual Load method**
- **The majority of pilots and controllers agreed that the times seen in the simulation were acceptable**
- **Controllers had very few messages / dialogs open and rarely got above a peak of 3 message (IM and non-IM) in the queue**
- **Controllers reported acceptable workload for CPDLC with Manual Load and CPDLC with Direct Load**
- **Average total transaction time was 34 seconds**

* At the time of the simulation development, RCP180 was derived for IM. However, after completion of the simulation, RCP180 was no longer specified. RCP130 was the next closest RCP type and was chosen for IM (RTCA and EUROCAE, 2014).

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Procedures

- **Both pilots and controllers found the A-then-P acceptable for both CDPLC with Direct Loading and Manual Loading**
  - IM clearance complexity did not seem to be an issue for A-then-P
- **However, both expressed concerns about using A-then-P in a voice environment**
  - The reasons were unclear
  - While both groups expressed concerns about A-then-P use during voice communications, they did not seem to think P-then-A was better

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Interfaces

- **Majority of controllers reported finding both the IM and CPDLC interfaces individually acceptable**
- **Vast majority of controllers reported that the direct loading of the IM clearance into their IM system was acceptable**
- **Majority of pilots also reported finding both the IM and CPDLC interfaces individually acceptable**
  - Some pilots expressed confusion when messages spanned multiple pages on the MCDU. Some reported missing information due to not realizing additional detail was on another page
- **Pilots used the direct loading feature 100% of the time**
- **Across complexities, pilot responses were mixed on the acceptability of manually entering the voice-issued IM clearances into the flight deck IM system. The Voice with Manual Load was consistently rated poorer than both CPDLC with Manual Load and CPDLC with Direct Load**

Simulation Assessment

- **Vast majority of pilots and controllers agreed that the overall simulation was effective as a context for evaluating IM and CPDLC**
  - One pilot disagreed and wondered how it would work in Denver “where clearances are assigned later in the arrival”
  - One controller had a neutral rating and commented that it was effective for a “non-complex environment”
- **Vast majority of pilots and controllers reported that they received an adequate amount of training**
  - One pilot reported confusion about which clearances override the IM clearance but reported it became clearer later in the simulation
  - The other pilot reported wanting to receive material prior to the simulation to better understand IM and CPDLC

"Overturned Rocks"

- **Based on and within the context of the simulation…**
  - IM and CPDLC can work well together
  - ATC and flight crews can work in a mixed equipage environment
    - Absolute (non-IM) and relative spacing (IM)
    - Voice and CPDLC
- **CPDLC may be required for more advanced NextGen concepts that require complex communications**
- **Consideration should be given to the integration of new concepts into planned CPDLC interfaces**
  - To prevent cumbersome interfaces requiring too many button clicks or unnecessary viewing of multiple displays / display areas

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Key Recommendations

Select Key Recommendations (1 of 2)

- **Retain, as is, the IM messages tested in this simulation**
- **Consider these results as support for validation of RCP130**
- **Require / allow controllers to use the advanced organizer "Interval spacing clearance available. Advise when ready to copy" when using voice communications for complex IM clearances**
  - Pilots reported wanting this communication. It allows them to prepare for the complex clearance. Controllers currently use this type of communication for complex navigation clearances. This would be an extension of that
- **Conduct further research to determine how to manage complex IM clearances over voice communications**
  - For example, certain clearance elements could be included in published arrival procedures or the IM clearance could be broken into two separate messages (one with the basic information and another with the reference aircraft IFPI)

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Select Key Recommendations (2 of 2)

- **Consider 8 – 10 elements the potential maximum number of elements / level of complexity for IM clearances over voice communications in the en route environment**
  - Four to 7 elements may be a more reasonable number of elements based on past IM research but may still have some potential for communication issues
- **Ensure the reference aircraft trajectory information (i.e., IFPI) is kept to a minimum, especially for voice communications**
  - IM clearances with 10 elements proved challenging in this simulation. The IFPI was often cited as the problematic element
  - Consider limiting the IFPI to fewer than 2 – 5 elements
- **Retain the planned A-then-P method of IM clearance acceptance when using CPDLC communications**

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Abbreviations and Acronyms

- A-then-P – Accept-then-Process
- AFS – Flight Standards Service
- AGD – Auxiliary Guidance Display
- AIR – Aircraft Certification Service
- ASPA – Airborne Spacing
- ATC – Air Traffic Control
- ATS – Air Traffic Services
- CDTI – Cockpit Display of Traffic Information
- CPDLC – Controller Pilot Data Link Communications
- DSI – Display System Integration
- EFIS – Electronic Flight Instrument System
- ERAM – En Route Automation Modernization
- EUROCAE – European Organization for Civil Aviation Equipment
- FAA – Federal Aviation Administration
- FIM – Flight deck Interval Management
- FL – Flight Level
- GIM – Ground Interval Management
- GIM-S – Ground Interval Management – Spacing
- HDG – Heading
- HITL – Human-in-the-loop
- HMI – Human Machine Interaction
- IAS – Indicated Air Speed
- ICAO – International Civil Aviation Organization
- IFPI – Intended Flight Path Information
- IM – Interval Management
- IM-S – Interval Management – Spacing
- ITT – In-Trail Time
- MCDU – Multifunction Control and Display Unit
- MSG – Message
- MTE – Meet Time Error
- NextGen – Next Generation Air Transportation System
- P-then-A – Process-then-Accept
- RCP – Required Communication Performance
- RPA – Brickyard
- RQST - Request
- RTCA – RTCA
- S – Seconds
- SBS – Surveillance and Broadcast Services
- SC – Special Committee
- SNT – Sent
- STA – Scheduled Time of Arrival
- TPCS – Third Party Call Sign
- WG – Working Group

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