Towards Routine Global, Commercial RPAS Operations

Presented To:
NASA Multi-Vehicle Control Working Group

Approved for Public Release. This presentation does not contain technical data per ITAR 22 CFR parts 120-130.
Global effort to Integrate UAS/RPAS into the Aviation System

• **Unmanned Aircraft System (UAS)**
  
  - Globally accepted term for small UAS (sUAS), i.e. Part 107
  
  - Primarily U.S. centric term in the context of large aircraft

• **Remotely Piloted Aircraft System (RPAS)**
  
  - Globally accepted term for large aircraft
  
  - Remotely Piloted Aircraft (RPA)
  
  - Remote Pilot Station (RPS) with Qualified Remote Pilot
  
  - C2 Link (i.e. Control and Non-Payload Communication [CNPC])

• **ICAO RPAS Panel**
  
  - International Operations under Instrument Flight Rules (IFR)
  
  - Updates to SARPS and PANS within many Annexes

• **National and Regional Regulations**
  
  - FAA’s Drone Advisory Committee (DAC)
  
  - JARUS (Joint Aviation Regulators of Unmanned Systems)
  
  - **FAA UAS in Controlled Airspace Aviation Rulemaking Committee (ARC)**

• **Standards Development Organizations**
  
  - RTCA, EUROCAE, ISO, ASTM
  
  - ARINC

SARPS = Standards and Recommended Practices

PANS = Procedures for Air Navigation Services
FAA ARC: Use Case 1
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ICAO RPAS Operations

- Major Terminal Maneuver Area (TMA) (Class B in US)
- Standard Terminal Arrival Route (STAR)
- Standard Instrument Departure (SID)
- Instrument Approach Procedure (IAP)
- Towered Airport
- IAF
- FAF
- Enroute
- International Flight Plans and Coord.

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ICAO RPAS Framework: Key Concepts

• **RPAS = RPA and RPS with C2 Link to connect RPIC**
• **RPIC may change throughout RPA flight**
  – Each RPA has one RPIC (note the order!)
  – RPIC may delegate to RP
  – “in Command” does not imply level of “Control”
• **International Operations under IFR**
  – Integrates with CNS/ATM/Aerodrome infrastructure
  – B737/A320 not quadcopter
• **C2 Link meets RLP and managed by C2CSP**
  – RLP similar to RNP, RCP, RSP concepts
  – RLP depends Airspace, Phase of Flight, Procedure, etc...

RPAS = Remotely Piloted Aircraft System
RPS = Remote Pilot Station
C2 Link = *Not an acronym*
RPIC = Remote Pilot in Command
IFR = Instrument Flight Rules
RLP = Required Link Performance
C2 CSP = C2 Link Communication Service Provider
Multi-Aircraft Control Concept

Control Architecture will vary by Phase of Flight and Work Load

Phased Approach: Design for M:N but start 1:1, while collecting data for Fully Automated

* Ratio Numbers are notional
High Density/Complexity Operations

- Dense ≠ Complex, and Complex ≠ Dense
- Highly Dynamic Operations
  - Efficiency depends on rapid changes
- High Communication Tempo
  - Rapid Voice Comm.
- Mixed Equipage or Performance
  - IFR/VFR
  - Voice/Data Comm.
  - Instrument/Visual
  - Speeds and Maneuverability

IFR = Instrument Flight Rules
VFR = Visual Flight Rules
Oceanic Airspace

- **Highly Structured Performance-based Routes**
  - RNP/RNAV
  - RSP: SB-ADS-B, ADS-C
  - RCP: Datacomm
- **Low Communication Tempo**
  - TET through RLP
- **Non-Dynamic Operations**
  - High Levels of Onboard Automation
- **Dispatcher**

*R* Ratio Numbers are notional

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**Definitions**
- **RNP** = Required Navigation Performance
- **RCP** = Required Communication Performance
- **RSP** = Required Surveillance Performance
- **RLP** = Required Link Performance
- **ADS-B/C** = Automatic Dependent Surveillance – Broadcast/Contract
- **TET** = Transaction Expiration Time

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Low Density/Complexity Airspace

- **Low Density Airspace**
  - Enroute Continental
  - Low Altitude outside of Class B or Mode C Veil
  - Metrics used by ATC (?)

- **Low Complexity**
  - Similar Performance
  - Similar Equipage
  - Similar Procedures

- **Working in Teams enables task sharing**

- **M:N ratios increased using**
  - Onboard Automation
  - Digitizing and/or Automating ATC instructions
  - Stakeholder Experience
Structured Routes in Dense Airspace

- **Structure and Routine brings lower complexity**
  - Airways and Procedures
  - Limitations and Boundaries

- **Performance-based Requirements to increase time/space buffers**
  - Not “Segregation”
  - ARC: Local Area of Operations

- **M:N ratios increased using**
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  - Digitizing and/or Automating ATC instructions
  - Stakeholder Experience

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Control Architecture Progression

1:1 Pilot to Aircraft Operations

One Pilot controlling a single Aircraft as “Remote Pilot in Command”
Build on Experience with Current-day CS/RPS
COTS Hardware aligned with Large §23 Single Pilot Flight Deck (e.g. Honda Jet)
Central Pilot Location with Airport locations as required by Authorities
Networked RLOS C2 Datalink when Satcomm doesn’t meet requirements
Onboard Automated Contingency Management
Design for M:N

Collect data to substantiate M:N

M:N Pilot to Aircraft Operations

Many Pilots controlling Many Aircraft with a single RPIC
1:1 Operations during Contingencies
Retain 1:1 HW/SW for subset of N aircraft in operation
“Clean Sheet” Design of Control Center
Central Pilot Location
Networked RLOS C2 Datalink when Satcomm doesn’t meet requirements

Collect data to substantiate “Fully Automated” Operations

Fully Automated Operations

One Pilot “monitoring” Many Aircraft as RPIC
Automated ATC Voice Rx/Tx or digital ATC Instructions
1:1 Operations during Emergencies
Onboard Automated Emergency Management
Redefine role of the “Pilot” and “Pilot In Command”, maybe more aligned with Dispatcher role

Pilot is in the system for Efficiency, not Safety
Primary Gaps / ‘Research Questions’
Context: Controlled Airspace

• **Pilot-ATC Voice/Data Communications**
  – Latency and TET for two-way radio communication outside of busy terminal area
  – Ability to mix Voice and Datacomm
  – Ground-ground Voice and Digital Communication
  – One pilot listening/talking to two or more controllers
  – RCP Requirements:
    • Continental (high, medium, low density)
    • Terminal area (high, low density)

• **Automating Functions that currently require Pilot Monitoring**
  – RVSM
  – RNP – Approach, Landing, Take-off
  – Automated ACAS (DAA)

• **Contingency / Emergency Management**
  – Automating pilot-centric responses

• **Integration with Airline Operations**
  – Role of Dispatcher and sharing responsibilities

• **Structure to Increase M:N Ratio**
  – Automation requirements
  – Operational Boundaries/buffers

• **Data/Experience Collection**
  – Similar to ETOPS, what data could airlines bring to regulators to increase ratios?

• **Human Factors Guidance**
  – Is existing guidance “good enough” or do we need more standardization of specific items?
  – How did NASA contribute to Advanced Flight Decks?

• E.g. Emergency Forced Landing
  – Level of Pre-coordination and pre-approval with ANSP
  – Retain ability to revert to 1:1? For what percentage of fleet?