NSF National Workshop on Transportation Cyber-Physical Systems (CPS)

Breakout Session: UAVs

Dr. Christine M. Belcastro, Moderator
NASA Langley Research Center

Dr. Sumit Kumar Jha, Scribe
University of Central Florida

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Goals / Capabilities Enabled by CPS Autonomy Technologies (1)

- 2015 Congress Challenge – deploy UAS for civil use
- Single-Pilot and Pilot-Optional Operations for Commercial Transports
  - What is the challenge? Human as source of fault-tolerance; Variable autonomy; Dynamic partition of authority between human and UAS.
  - Terascale computing power available on-board. Faster than real-time safety monitoring.
  - Cargo vs Passenger
  - Current vs Future National Airspace System (NAS)
  - Nominal vs Hazardous Conditions
- Improved Monitoring & Disaster Response
  - Forest Fire
  - Border Patrol
  - Other
- Long-Duration Science Observation
  - Atmospheric / Environment
  - Other

Goals / Capabilities Enabled by CPS Autonomy Technologies (2)

- Point-to-Point and On-Demand Door-to-Door Autonomous Transportation of People & Goods in Future NAS
  - Integrated Muti-Modal Implementation (Ground and Air / Flying Car)
  - Other
- Co-ordinated and super-dense UAS operations
  - TBD
- Reliability vs. Economics: UAS is on one extreme and commercial aircrafts (3X) are on other extreme.
  - Possible danger to general pouplation
- Supervisory control – beyond RC

Possible Technology Solutions (I)

- Real-time safety monitoring
  - based on heightened CPU capability
  - Definition of safety (temporal logics)
- Resilience
  - off-nominal and hazardous conditions
- Variable autonomy capability
- Technology scalability
- Synchronized operations
  - Large-scale distributed communications and control for (through GPS satellites).
  - Space / time segment deduction & coordination
- Local optimization methods and system architectures for air-traffic management.
- Detection and identification of UAV threats.
- Cost-reduction for complex, safe and secure software systems.
- Verification & Validation
  - Analysis and Simulation
  - Reduction in physical flight tests.
  - Open-source models and simulations (academia, government, and industry)
  - Nonlinear simulations, Robustness, Uncertainty Quantification, Loss of Control - Prevention and Recovery

Possible Technology Solutions (II)

- New Clockwork for Time-Critical Systems
  - Dr. Gill's workshop report.
- Learning and autonomy methods and tools
  - Verifiable and certifiable learning tools
  - A priori verifiable learning algorithm
  - Bounded Uncertainty
    - Corner cases and their handling by inductive learning algorithms
- Control of UAVs in tight spaces, no line-of-sight
  - E.g. infrastructural assessment
- Control algorithms in GPS-denied environments
- Multi-modal UAVs (air and ground)
  - Support infrastructure for UAVs
- Situational awareness
  - Organizational vs. mission-oriented; autonomous systems.
- Sense and avoid
  - Broader than human abilities – radar
- Application-driven requirements development
  - Definition of use-cases; RTCA set of 34 missions.
- Corridor allocation, management and enforcement
  - Clear dichotomy between passenger/military aircrafts vs. private micro-UAS
- Network-controlled CPS
  - Super-dense multi-vehicle systems

Capabilities-Driven Research Directions / Roadmap

- 5-10 years
  - Improved Crew Situation Awareness / Guidance under Off-Nominal & Hazardous Conditions
  - Limited Military (Small) UAVs in Commercial Airspace
- 10-15 Years
  - Operator-Engaged Recovery
  - Industrial UAVs in Commercial Airspace (Local / Regional)
- 15-25 Years
  - Resilient Control Augmentation to Baseline Control System
  - Widespread Industrial UAVs in Commercial Airspace (Cargo Transports)
- >25 Years
  - Real-Time Autonomous Systems for Transport Aircraft (Passenger)
    - Autonomous control interventions
  - Real-Time Safety Assurance Systems

Need to sync with FAA, RTCA and other efforts.

Backup

Air Transportation Challenges

- System-wide Safety Assurance at All Levels
  - Current & Future NAS
  - Vehicle-Centric
  - NAS / Infrastructure & ATC/ATM
- Technology Certification
  - Validation & Verification (V&V) of Safety-Critical Autonomous Systems
    - Demonstrated Compliance with FARs
  - Human Interfaces (Onboard / Remote)
    - Variable Autonomy
- Trust
  - FAA
  - Airframe Manufacturers
  - Cargo Industry
  - Traveling Public
- Other

Discussion Outline

- Goals / Capabilities Enabled by CPS Technologies
- Air Transportation Challenges
- Technical Challenges
- Research Directions and Roadmap
- Other
  - Key Issues / Impediments

Technical Challenges

- Accident Prevention - Understanding Complex Problems
  - Aircraft Loss of Control (LOC)
  - Controlled Flight into Terrain (CFIT)
  - others
- Autonomous Control
  - Real-Time Resilience under Hazardous Conditions
    - Hazards / Effects Detection, Identification, Mitigation
  - Dependable Sense and Avoid (Fixed & Moving Obstacles)
  - others
- Real-Time Safety Assurance
  - Vehicle-Centric
  - Multiple Vehicles
  - NAS / Infrastructure (including Faults and Security Threats)
  - others
- V&V / Certification
  - Analysis, Simulation, & Testing
  - Reliability under Technology Malfunctions (Error Propagation)
  - Model / Simulator Fidelity for Hazardous Conditions
  - Test Scenarios
  - Others
- Other

Other

- Key Issues / Impediments

- Other