Advanced Air Mobility Operations & Automation Part II Technical Lecture

AIAA Aviation Flight Test Technical Committee

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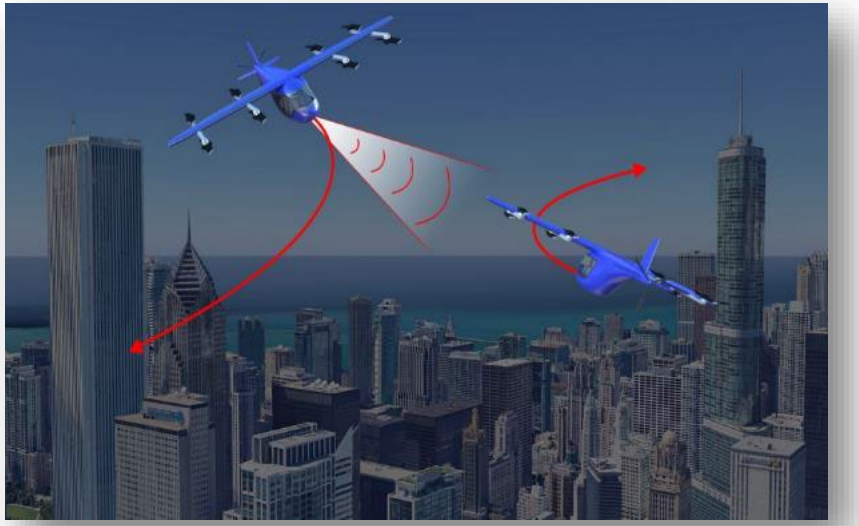
HPA Background

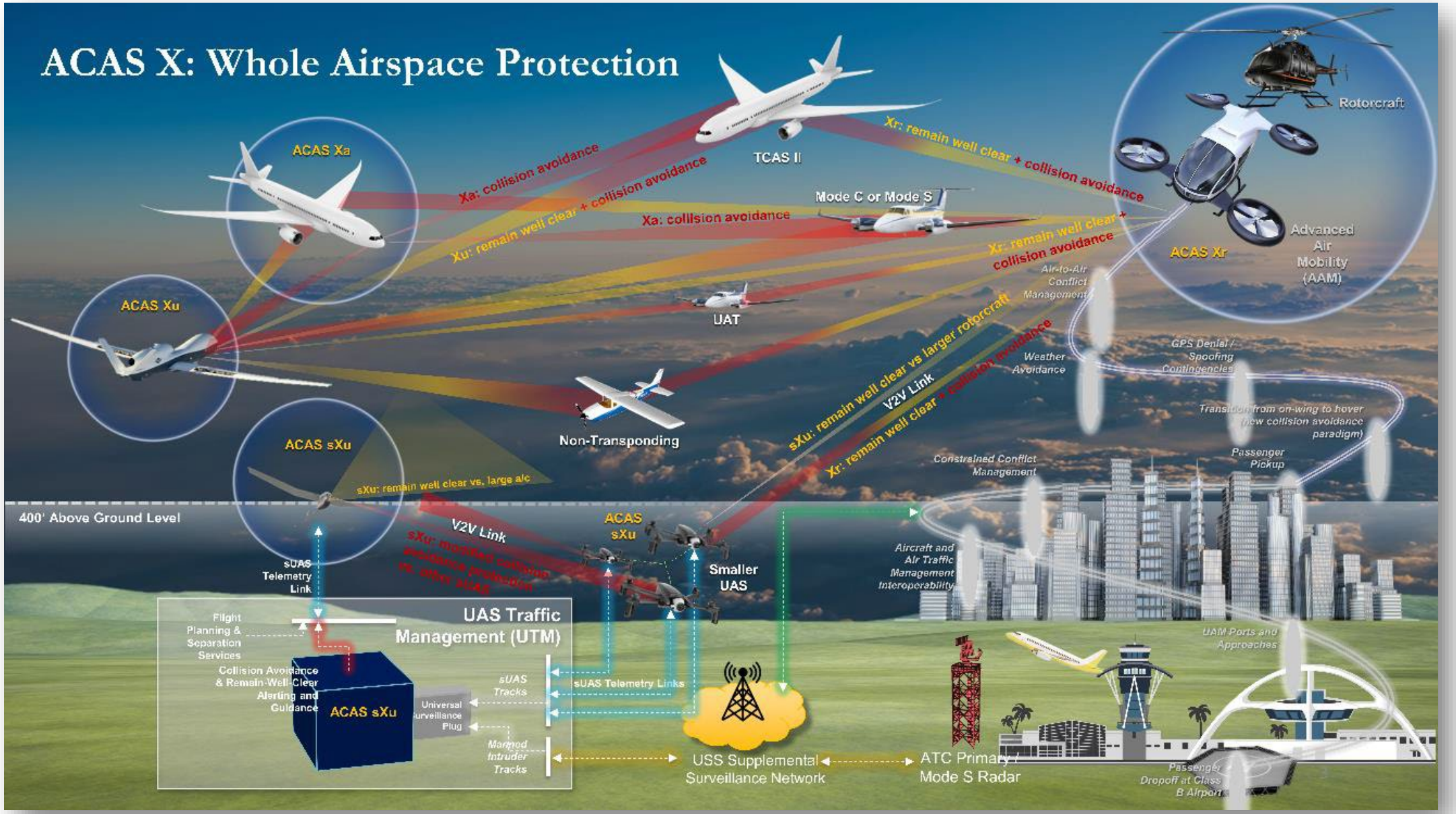
- Hazard Perception and Avoidance (HPA) is a technical area under AAM's Automated Flight and Contingency Management (AFCM) sub-project
  - Collecting human-in-the-loop simulation and flight test data to inform standards development for a tactical avoidance system for AAM
  - Building toward UML-4; assuming an onboard pilot with increased automation support



- Using the FAA's Airborne Collision Avoidance System for Rotorcraft (ACAS X_R) as our tactical conflict detection and resolution technology
  - ACAS X_R is the latest variant of ACAS X – the next generation replacement of TCAS II
    - Designed for crewed and uncrewed helicopter & AAM platforms
  - ACAS standards development managed by RTCA SC-147

* ACAS logo borrowed with permission from the ACAS X development group

ACAS Overview



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ACAS X_R Alerting

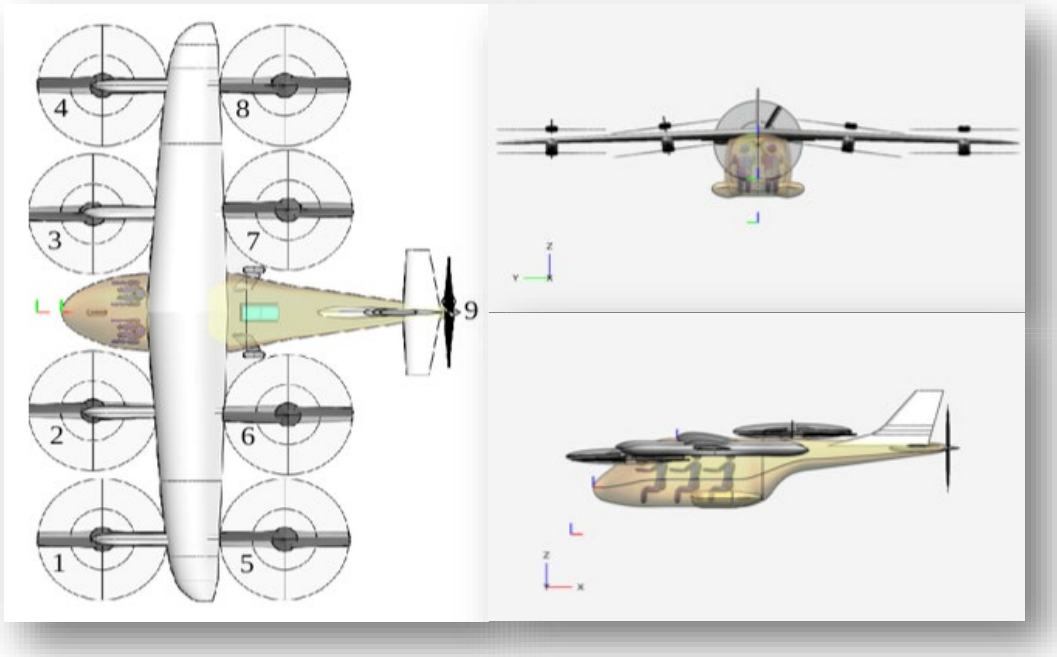
- ACAS X_R provides *Detect and Avoid* (DAA) functionality through caution-level alerting & guidance
  - Previously developed for large UAS
  - DAA alerts comply with UAS DAA MOPS (DO-365B)

- ACAS X_R also issues *Collision Avoidance* (CA) functionality via Resolution Advisories (RAs)
  - **Vertical** RAs command a *target vertical speed*
  - **Horizontal** RAs command a *target track*
  - **Blended** RAs command a target track **and** target vertical speed *simultaneously*

HPA Simulation Overview

- HPA performed two human-in-the-loop simulations at NASA Ames Research Center in 2022 as build up to 2023 Integration of Automation Systems (IAS) Flight Test 1
  - Part Task Simulation 1 in April 2022 & Full Motion Simulation in August 2022

- Simulations utilized hybrid electric Vertical Takeoff and Landing (eVTOL) aircraft model
  - Lift Plus Cruise (LPC) model developed by NASA's Revolutionary Vertical Lift Technology (RVLT) project
  - Capable of fully transitioning from thrust-borne flight to wing-borne lift
  - 8 lifting thrusters, with two blade fixed-pitch propellors
  - Nominal Battery Range: 50 nm/60 minutes



Part Task 1 Simulation

- 12 helicopter pilots flew an eVTOL flight model under VFR, in a fixed-base simulator
- Objectives
  - Characterize pilots' response to ACAS X_R alerting & guidance in forward flight only
  - Collect data on the effectiveness of the ACAS X_R guidance during manual and automated maneuvers
  - Collect data on the utility of automated RA maneuver capability
  - Collect pilot feedback of overall simulation fidelity

Part Task 1 Results

Detect and Avoid

- DAA alerting & guidance helpful for situational awareness
- Quick response times
- More vertical maneuvers chosen than seen in UAS studies

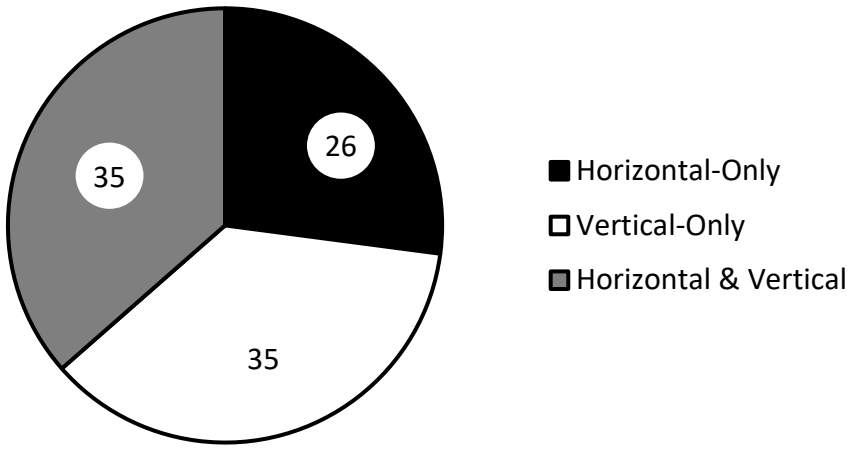
Resolution Advisories

- Response times easily met 5-second assumptions
- ACAS over-relied on horizontal RAs: update number and size
- Lack of terrain & obstacle awareness led to less trust & non-compliance

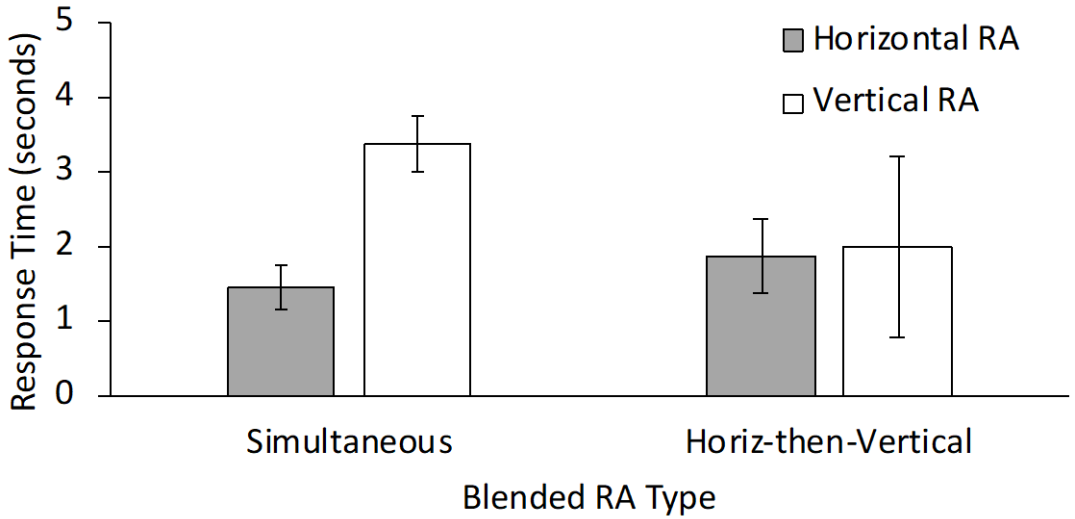
Automated Maneuvering

- Half preferred automatic maneuvers
- Variable did not significantly impact objective metrics
- Pilots consider terrain and obstacle integration as critical to the safety of the automation

DAA Maneuvers



Blended RA Response Times



Full Motion Simulation

- 6 helicopter pilots flew NASA Ames' Vertical Motion Simulator
- Objectives
  - Collect pilot feedback in a higher-fidelity environment
  - Characterize pilots' response to ACAS X_R alerting & guidance in different phases of flight
    - Cruise, hover, & approach
  - Collect data on the effectiveness of the ACAS X_R guidance under different ACAS configurations
    - Collision Avoidance System (similar to TCAS II)
    - Detect And Avoid (developed for uncrewed)

ACAS X_R Configuration Examples

CAS Configuration

- *Traffic Advisory* (TA) issued first
  - Visual & aural alert (“Traffic, Traffic”)
  - Not used to maneuver - no maneuver guidance
  - Pilot can try to visually acquire traffic

- *Resolution Advisory* (RA) eventually issued
  - Visual & aural alert (e.g., “Climb, Climb”, “Turn Right, Turn Right”)
  - Vertical and/or horizontal guidance dictates how pilot maneuvers
  - Maneuver expected within 5 seconds

DAA Configuration

- *DAA Corrective* alert issued first
  - Visual & aural alert (“Traffic, Avoid”)
  - Guidance “banding” used by pilot to determine if/how to maneuver
  - Airspeed, heading and vertical speed bands

- *Resolution Advisory* (RA) issued if not resolved
  - Presentation same as TA/RA Mode

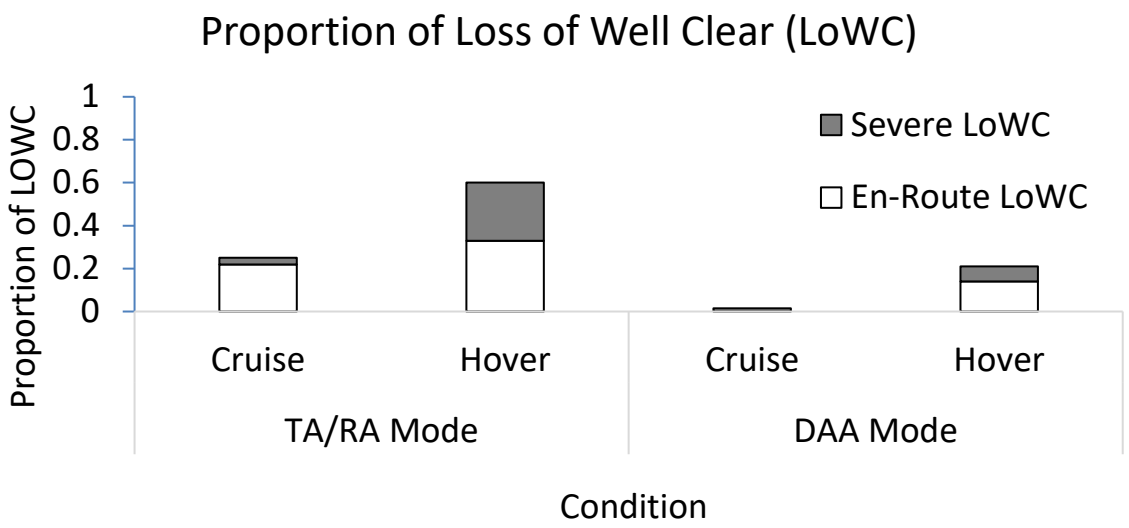
Full Motion Simulation Results

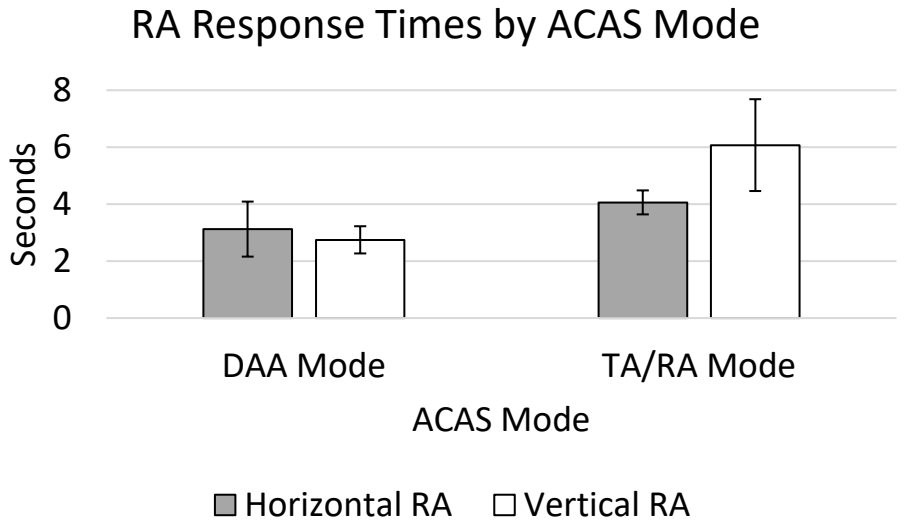
Flight Phases

- ACAS rated as *most* effective in cruise
- Rated *least* effective in hover
- Pilots frequently non-complied with RAs in terminal area due to inappropriate guidance
- Pilots frequently stopped complying with Descend RAs due to proximity to terrain

DAA Feedback

- Pilots rated the DAA Mode as useful in an onboard setting
- Half of pilots still preferred CAS Configuration
- DAA airspeed guidance rated as least effect DAA element



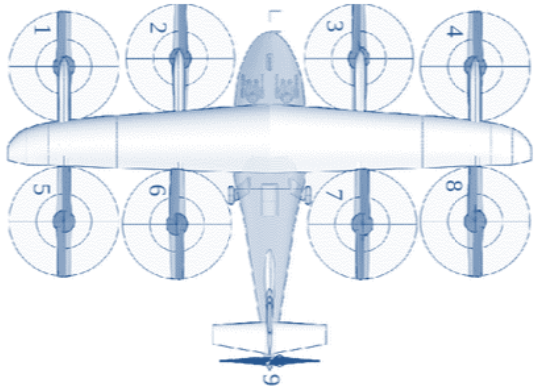


Next Steps

- Simulation results have been shared with RTCA Special Committee 147 (SC-147)
  - SC-147 is currently developing the ACAS X_R MOPS
  - Close involvement with the Operations Working Group (OWG) which is responsible for ensuring operational acceptability of ACAS X_R to rotorcraft pilots & operations

- Ongoing flight test with Sikorsky Autonomous Research Aircraft (SARA) building on previous simulations
  - Testing latest version of ACAS X_R in scripted encounters against ADS-B-equipped intruder
  - Building off Full Motion sim to test X_R in different phases of flight under both Xr Configurations (DAA & CAS)
    - Pilots' interaction with automated RA function and low-altitude RAs also included in encounter set

Questions



Thank you

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