

Defining Command, Control and Communications (C3) for Unmanned Aircraft Systems (UAS)

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H A L E R O A i n t h e N A S



Overview

- **Access 5**
- **ATC Communications**
 - Notional architectures
 - Requirements
- **C2 Communications**
 - Notional architectures
 - Requirements
- **Requirement Verification Process**
 - Analysis: Compliance Matrix
 - Simulations
 - Flight Tests
- **Questions**



Access 5

- **Vision**

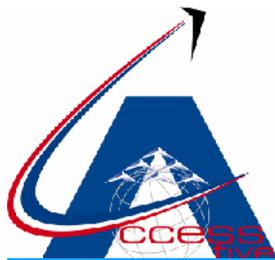
To operate High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the National Airspace System (NAS)

- **Mission**

Through a strategic Government/Industry Alliance, accomplish the Access 5 vision by developing standards, regulations, and procedures; demonstrating technologies; and implementing infrastructure necessary to meet national priorities

- **Objective**

Enable a commercial/civil HALE UAS market in the US



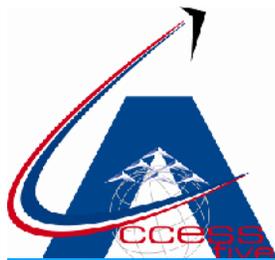
Access 5 Participants

Government

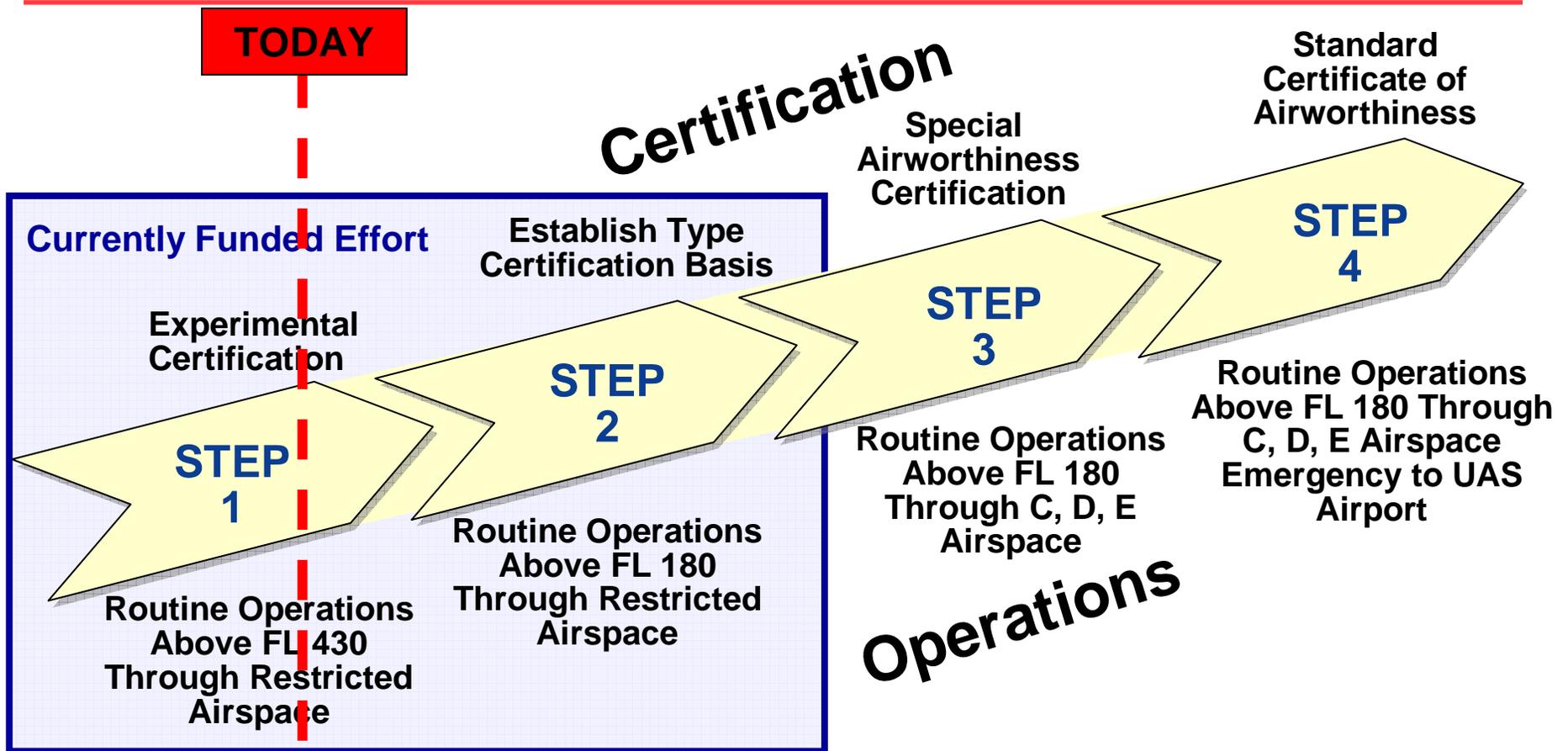


The UAV National Industry Team



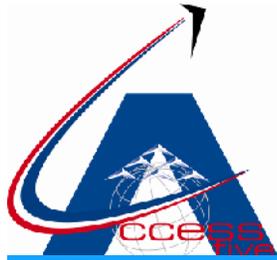


Access 5 Approach



Achieve Routine Access in the NAS for HALE UAS

HALE ROA in the NAS



Command, Control & Communications (C3)

- **Mission**

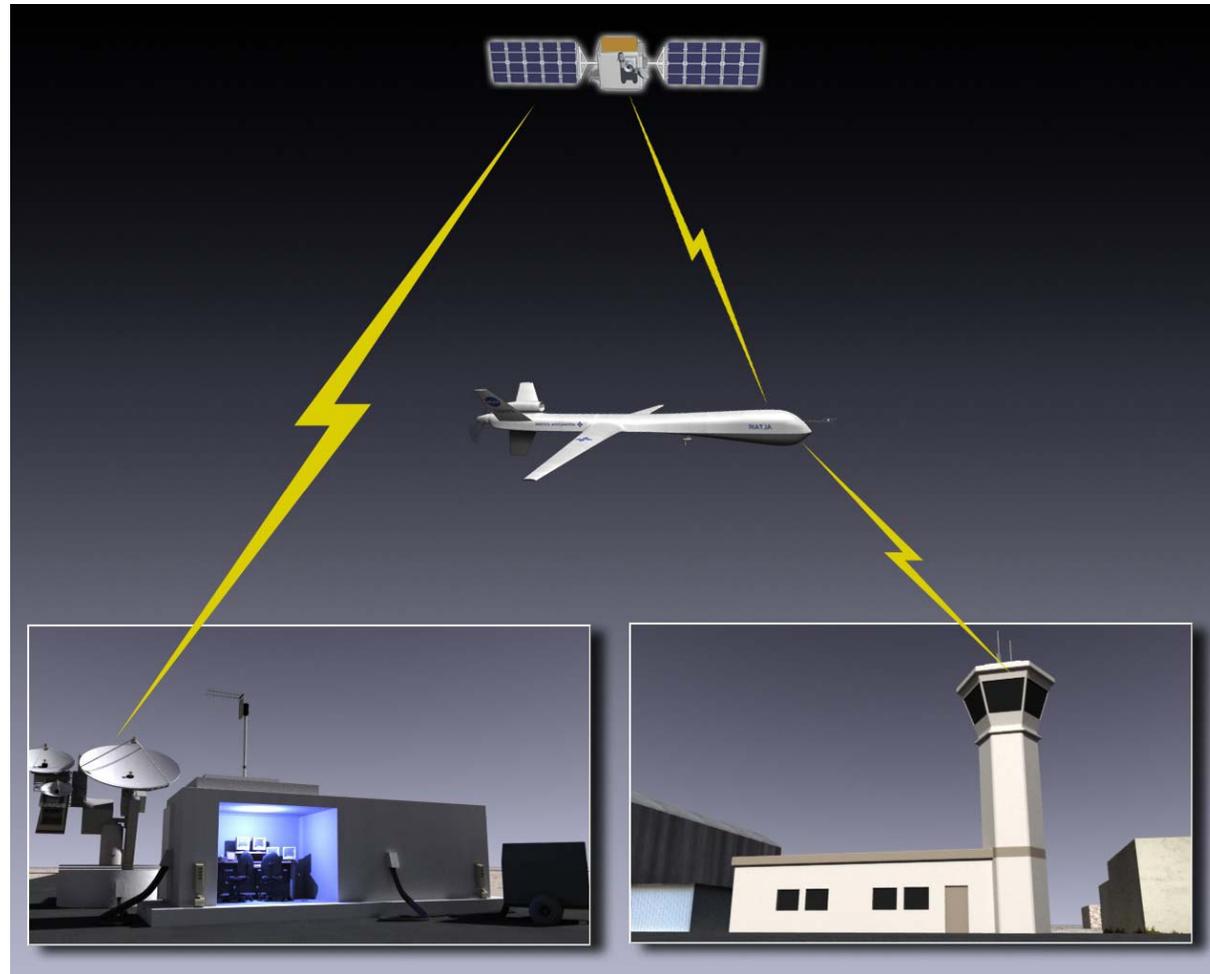
- Establish the minimum set of functional requirements for a HALE UAS to operate routinely and safely in the NAS

- **Major Elements**

- ATC Voice Communication
- Command & Control (C2) Communication
- Access 5 does not address Payload Data



Notional ATC Communications Architectures



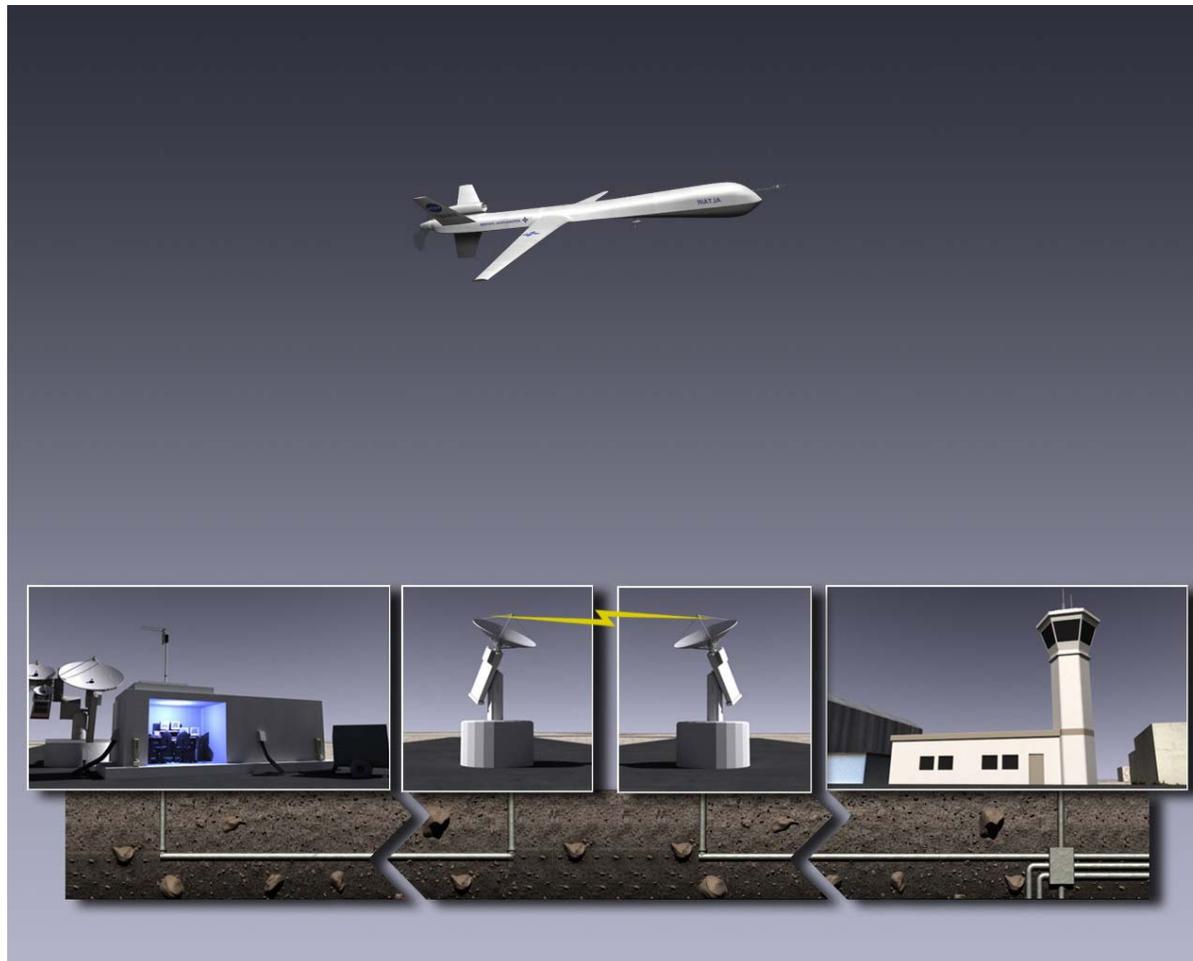
SATCOM w/Unmanned Aircraft as a relay

HALE ROA in the NAS



Notional ATC Communications Architectures (2)

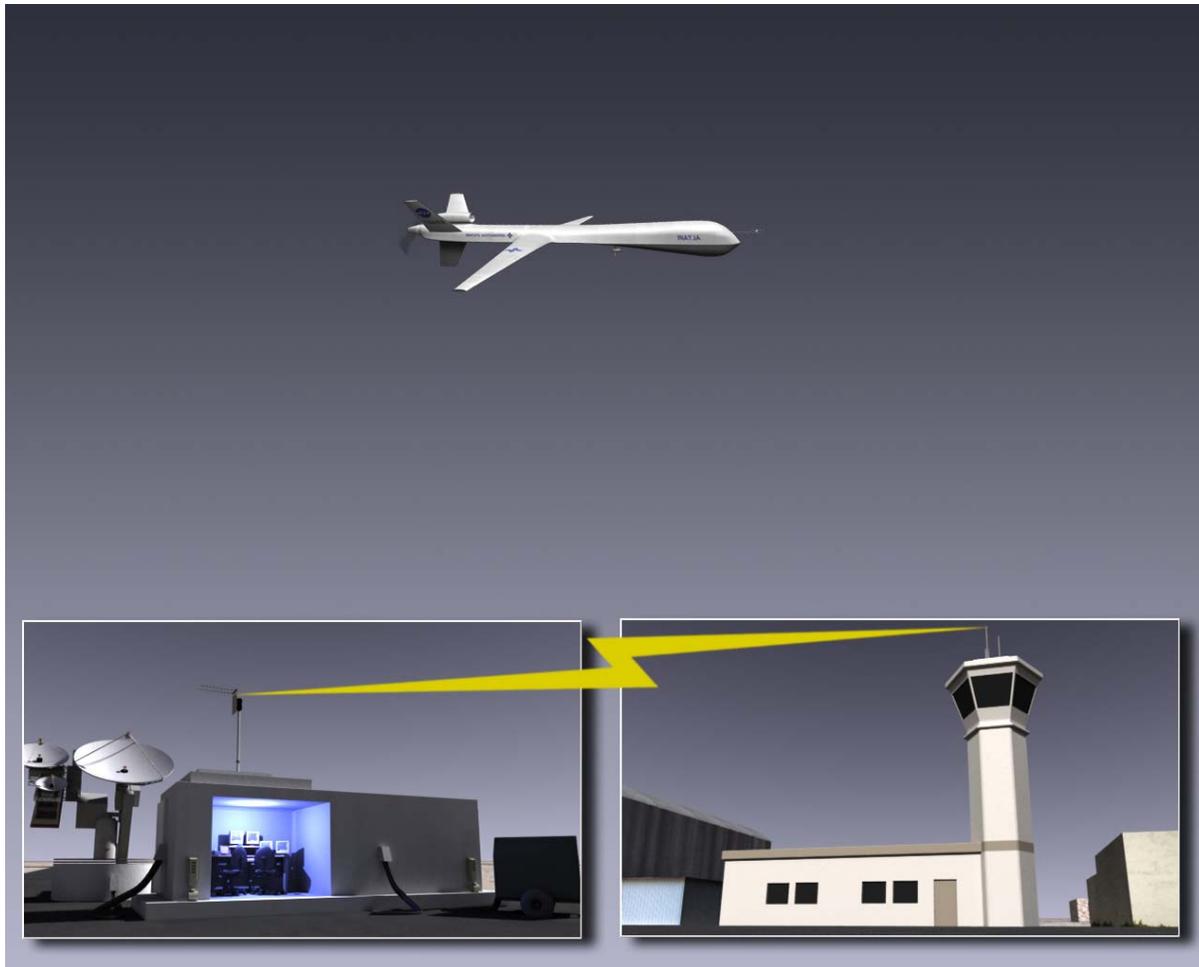
Landline to FAA facility



HALE ROA in the NAS

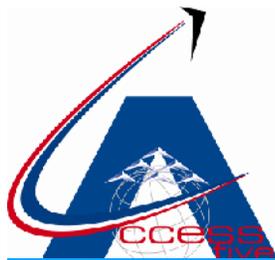


Notional ATC Communications Architectures (3)



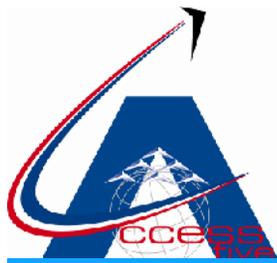
**VHF Line of Sight
w/local ATC radio
facility**

HALE ROA in the NAS



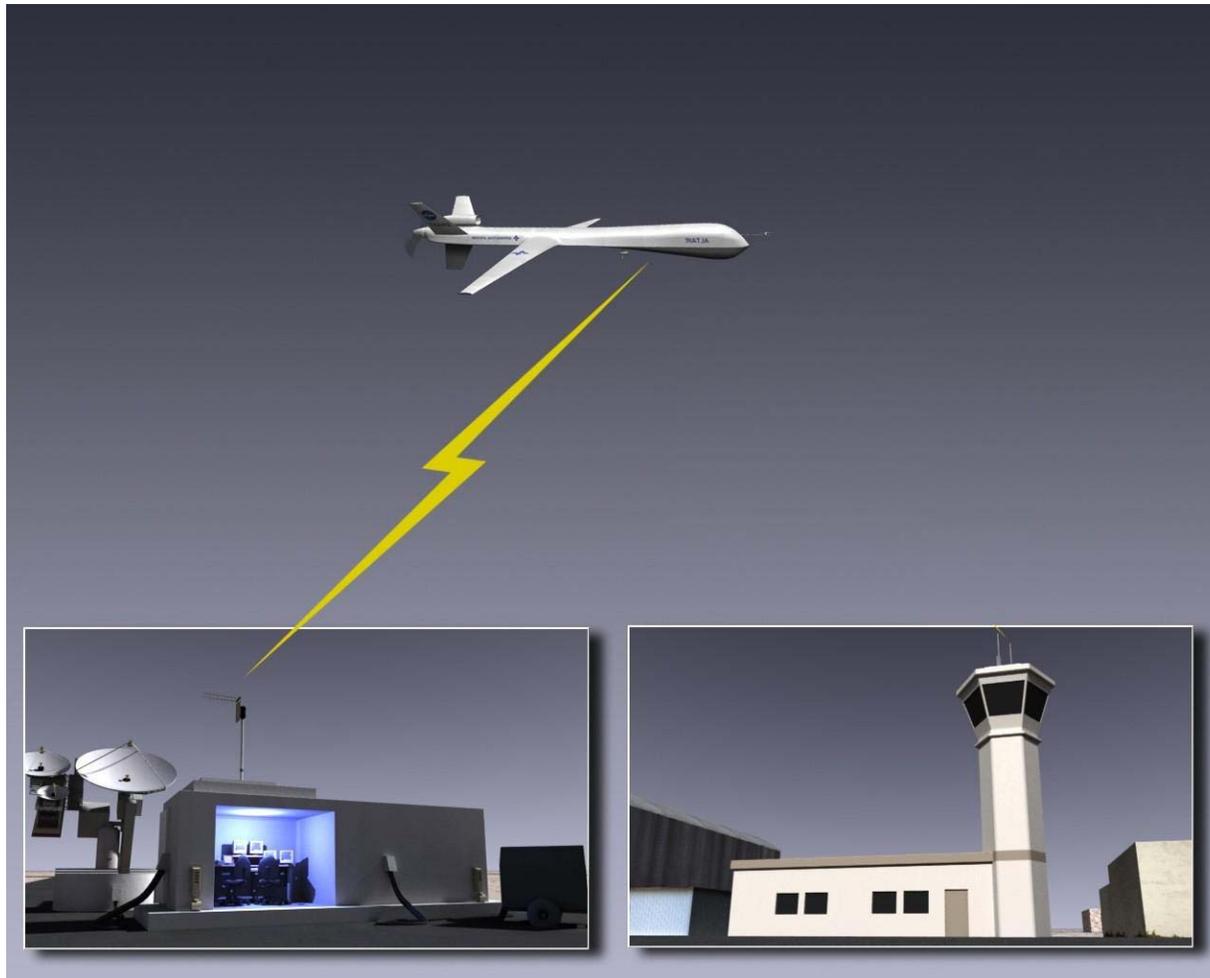
ATC Communications Requirements

- **Comply with current ATC regulations**
- **Integrate with the NAS by ensuring NAS system-level requirements are achieved**
- **Monitor (receive) ATC directives and other pilot voice traffic on the assigned channel**
- **Transmit voice to ATC and other pilots on the assigned channel**
- **Transmit on the channel only for the duration of a pilot transmit indication signal event (e.g. Push to Talk (PTT) signal)**
- **Tune the ATC radio to any ATC frequency**



Notional C2 Communications Architectures

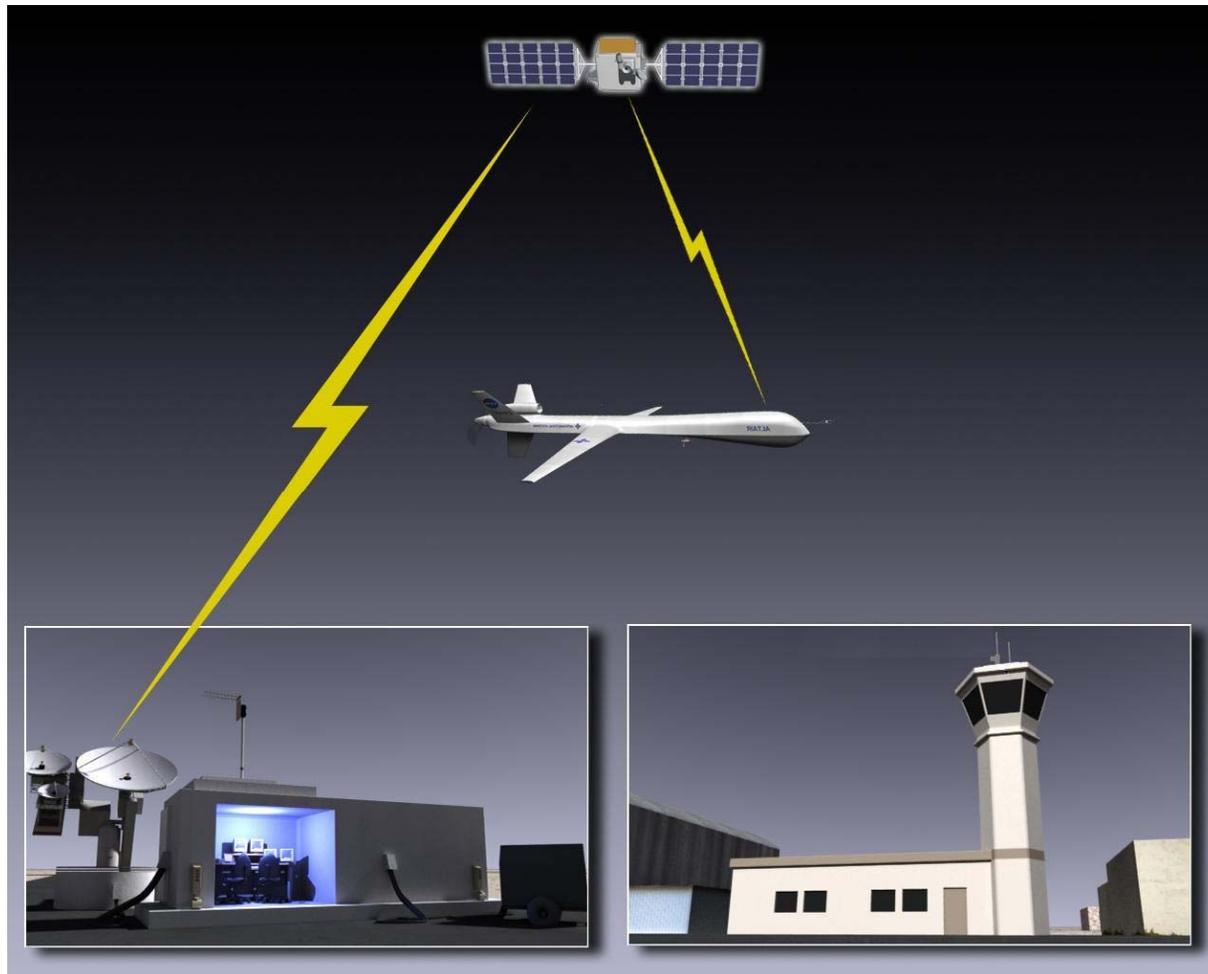
Line of Sight with Unmanned Aircraft



HALE ROA in the NAS



Notional C2 Communications Architectures (2)



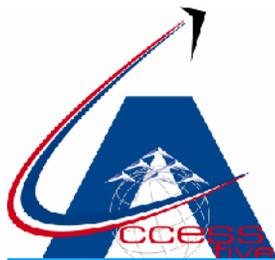
**Beyond Line of Sight
with Unmanned Aircraft**

HALE ROA in the NAS



C2 Communications Requirements

- **Perform information exchanges for UAS operations**
 - Provide uplink command and control communications between the UA and AVCS
 - Provide downlink command and control communications between the UA and AVCS
 - Ensure cohesive and consistent uplink and downlink operations
- **Provide communications procedures and protocols**
- **Provide communications to control safe flight and UA operations (i.e., the information that is exchanged)**
 - Provide situational awareness and health and status of the UA to the AVCS
 - Provide C2 directives to the UA
 - Provide capability to prioritize C2 information exchanges
 - Cooperatively coexist with other NAS Systems by successfully operating within the existing NAS RFI environments
 - Provide ability to distinguish each UA
- **Provide secure C2 link**
 - Prevent unauthorized access
 - Provide for resistance to jamming or interference
- **Support C2 link connectivity**
 - Provide command and control communications while transitioning between LOS and BLOS operations
 - Provide command and control communications while transitioning between different AVCS stations



Methods of Requirements Verification

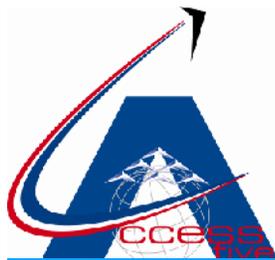
- Each functional requirement will be verified through one or more of the following methods
 - Analysis: Compliance Matrix
 - Simulations
 - Flight Test

Identifier	<u>Requirement</u>	<u>Verification Method</u>
Function 1	Comply with current ATC regulations	Analysis, Flight Test, Simulations
Function 5	Transmit on the channel only for the duration of a pilot transmit indication signal event (e.g. Push to Talk (PTT) signal)	Flight Test
Function 9c	Provide capability to prioritize C2 information exchanges	Analysis, Flight Test, Simulations



C3 Requirements Verification: Analysis - Compliance Matrix (ATC)

ROA - ATC Communications Functional Requirements	System 1	System 2	System 3	System 4	System 5	System 6	System 7
1. Comply with current ATC regulations	Green	Yellow	Red	Green	Yellow	Red	White
2. Integrate with the NAS by ensuring NAS system-level requirements are achieved	Red	Green	White	Red	Green	Yellow	Red
3. Monitor (receive) ATC directives and other pilot voice traffic on the assigned channel	Yellow	Red	Green	Yellow	White	Green	Yellow
4. Transmit voice to ATC and other pilots on the assigned channel	Green	Yellow	Red	Green	Yellow	Red	White
5. Transmit on the channel only for the duration of a pilot transmit indication signal event (e.g. Push to Talk (PTT) signal)	Red	Green	White	Red	Green	Yellow	Red
6. Tune the ATC radio to any ATC frequency	Yellow	Red	Green	Yellow	White	Green	Yellow



C3 Requirements Verification: Analysis - Compliance Matrix (C2)

C2 Communications Functional Requirements	System 1	System 2	System 3	System 4	System 5	System 6	System 7
7. Perform information exchanges for UAS operations	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement	Unknown
8. Provide communications procedures and protocols	Does not meet the requirement	Meets/exceeds the requirement	Unknown	Does not meet the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement
9. Provide communications to control safe flight and UA operations (i.e., the information that is exchanged)	Some potential for meeting the req.	Does not meet the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Unknown	Meets/exceeds the requirement	Some potential for meeting the req.
10. Provide secure C2 link	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement	Unknown
11. Support C2 link connectivity	Does not meet the requirement	Meets/exceeds the requirement	Unknown	Does not meet the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Does not meet the requirement
Overall	Meets/exceeds the requirement	Meets/exceeds the requirement	Meets/exceeds the requirement	Some potential for meeting the req.	Some potential for meeting the req.	Does not meet the requirement	Meets/exceeds the requirement
	LEGEND						
	Meets/exceeds the requirement						
	Some potential for meeting the req.						
	Does not meet the requirement						
	Unknown						



C3 Requirements Verification: Simulation

- Objective: Characterize the presence and effect of UASs on the communications infrastructure of the NAS through OPNET modeling and simulation

The screenshot displays the OPNET Modeler interface. On the left, the 'Node Model: A5_ROA' window shows a diagram with components: tx_gen, radio_tx, ant_tx, Rx, radio_rx, and ant_rx. On the right, the '(radio_tx) Attributes' dialog box is open, showing a table of attributes and their values.

Attribute	Value
name	radio_tx
channel	(...)
rows	1
row 0	
data rate (bps)	9,600
packet formats	all formatted, unformatted
bandwidth (kHz)	25
min frequency (MHz)	300
spreading code	disabled
power (W)	promoted
bit capacity (bits)	infinity
pk capacity (pks)	1,000
modulation	qpsk
rxgroup model	dra_rxgroup
txdel model	dra_txdel
closure model	dra_closure
chanmatch model	dra_chanmatch
tagain model	dra_tagain
propdel model	dra_propdel
icon name	ra_tx
channel [0].power	promoted

Extended Attrs.
 Apply changes to selected objects
Find Next OK Cancel

**UAS Radio
Link Model**



C3 Requirements Verification: Flight Test

- **C3 Flight Test Objectives**

- Evaluate the voice communication links between the UAS pilot and Air Traffic Control (ATC), for both Line-of-Sight (LOS) and Beyond Line-of-Sight (BLOS) operations
- Evaluate the command and control (C2) communication links between the UAS pilot and the UAS, for both Line-of-Sight (LOS) and Beyond Line-of-Sight (BLOS) operations



QUESTIONS??



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