NDIA Common UAV Architecture Study
Final Report - Executive Summary
12 August 2003

In Support of HQ USAF/XI, Warfighting Integration
What AF/XI Asked NDIA to Do

“... convene the major UAV platform companies to determine basis of a ‘plug and play architecture’ that could accommodate the evolving nature of platforms, mission control and ground station requirements”

“enable all UAVs to operate from all mission control stations”

The Problem

• “One of the costs [of UAVs] is the stovepipe nature of UAV operations”
  …each “controlled by a separate mission control station”
• “…the Air Operations Center (AOC) is becoming inundated with a proliferation of ‘tribal’ stovepipes requiring ‘tribal’-unique training, configuration-unique electronics and software, and an ever-increasing AOC bandwidth load and ground station logistics footprint”

The introduction of a new UAV into a theater of operations should not require a new, separate mission control station
The Problem Will Just Get Worse

Today’s Inventory

- Global Hawk – Northrop Grumman  Air Force
- VTUAV – Northrop Grumman  Navy
- Hunter – TRW  Army
- Predator & Predator B – GA-Aeronautical Systems  Air Force
- UCAV – Boeing  Air Force
- Pioneer – Pioneer UAV Inc.  Navy
- Shadow 200 TUAV – AAI  Army
- And many more  All Services

At least 138 different UAVs in production today

What NDIA Did for AF/XI

From the NDIA Study Terms of Reference (TOR):

- Seek industry consensus on recommendations for a UAV architecture that would provide universal interoperability between UAV platforms / sensors and UAV mission control stations.
  
  **Result: feasible; affordable if phased right**

- Explore UAV architectural requirements for operational interfaces, conversion standards, backward-compatibility, security, software, and training requirements, and the process by which those requirements are determined
  
  **Result: feasible technically but difficult politically**

- Concentrate on eliminating UAV stovepipes - recognize and anticipate external interfaces with MC2A, AWACS, Joint STARS, SBR, Allied and other systems
  
  **Result: feasible technically but stovepipes dominate**

- Address corporate buy-in and the level of industry commitment sufficient to share proprietary or company confidential information in order to develop a one-size-fits-all architecture
  
  **Result: feasible technically but incentives are essential**
APPROACH
“Big Five” Industry Leads

Boeing
GA-Aeronautical Systems
Lockheed Martin
Northrop Grumman
Raytheon

Kory Mathews
Jeff Hettick
Frank Mauro
Lew Berry
Joe Yavulla

104 people participated -- 39 on eight Sub-Groups
The Process

- Sorted commonality issues into functional areas
- Assigned Sub-Groups to address each functional area
- Documented “as is” condition in each functional area
- Projected “to be” architecture given the implementation of commonality initiatives
- Identified issues, developed conclusions, and recommended solutions

Consistent with DoD (C4ISR) Architecture Framework
Functional Area Breakout by Sub-Groups

- **CONOPS and Operational Interfaces** - Frank Mauro, Lockheed Martin, Chair
- **Human Systems Integration (HSI)** - Joe Yavulla, Raytheon, Chair
- **Mission Planning** - Eric Layton, GA-Aeronautical Systems, Chair
- **Air Vehicle Command and Control (C2) Interfaces** - Jeff Koehler, Northrop Grumman, Chair
- **Payload C2 Interfaces** - Gillian Groves, Raytheon, Chair
- **Communications** - Lew Berry, Northrop Grumman, Chair
- **Processor Architecture** - Dave Evans, Northrop Grumman, Chair
- **Logistics and Support** - Kory Mathews, Boeing, Chair

All work done on a *pro bono* basis
“AS IS”
Architecture Scorecard “as is”

Commonality

We have not found anyone in the UAV industry who is moving toward architecture commonality

CONOPS / Operational Interfaces - “as is” - RED

- UAV and AOC CONOPS will continue to evolve
- Operators will employ the delivered capabilities of each system to meet their training and warfighting requirements
- While similarities will be apparent, there is no driving need for CONOPS commonality across inherently different systems

However
- CAOC footprint considerations are forcing reconsideration of functional partitioning and physical location of its elements - UAV system flexibility will pay large dividends
- Communications is the “Long Pole” and will determine CONOPS and system options that will be available
- A top-level architecture can be common but must fit within the CONOPS
- AF / XI has the responsibility for developing this architecture
  - Industry can help

There are no inherent forces driving toward CONOPS commonality

Human Systems Integration (HSI) - “as is” - RED

• Trends in UAV systems
  – Toward highly autonomous UAVs
  – Increasingly significant on-board processing
  – More integrated C4I
  – Collaborative, multi-Air Vehicle mission operations
  – A single operator (“Mission Manager”) for multiple Air Vehicles
    • “Operator” and “pilot” categories becoming increasingly irrelevant
  – Increasingly sophisticated human-system interaction technologies
  – Higher-level mission management displays
  – More combined manned / unmanned operations for integrated strike packages

There is no natural, economic or legislative force driving any UAV program toward increased HSI commonality, although USAF training requirements will someday be a forcing function.
Mission Planning - “as is” - YELLOW

- **Predator**
  - Portable flight planning system (PFPS 3.2)
  - FalconView map server
  - PC-based
  - A / W / E developed by BAE Systems

- **Global Hawk**
  - AFMSS flight planning system
  - UNIX-based
  - A / W / E developed by Northrop Grumman

- **UCAV**
  - Boeing proprietary flight planning system
  - UNIX-based Data Exploitation Mission Planning Center (DEMPC)
    - Dark Star flight planning system evolved from DEMPC

**Migration to Joint Mission Planning System is within reach**

Air Vehicle C2 Interfaces - “as is” - RED

- There is no agreed-upon standard for Air Vehicle C2 interface commonality
  - UAV CONOPS are inconsistent in their approach to AV C2 interfaces
  - AOC-specific C2 requirements have not been formalized
  - UAV manufacturers have proprietary data concerns
  - Compatibility with external interfaces has not been established
  - Adaptability to future systems is not embedded
  - Backward-compatibility has not been addressed
  - C2 interface training is different for each UAV

For current systems, the C2 interface is with the UAV Operator Station

Payload C2 Interfaces - “as is” - RED

- Payload controllers see only their payloads
  - Imagery products use common standards, most other information exchange is non-standard
  - Mechanism for communicating with payloads is unique for almost all existing platforms
- No standard data format for C2 messages
- Payload contention for vehicle control addressed by human operators
- Information assurance limited to encryption and human judgment
- Bandwidth issues are generally static (no dynamic QoS)
- Any platform-platform interactions within constraints imposed by the communications links, doctrine, and CONOPS are human-mediated

Tasking is disjoint for all payloads - there is no standard method in the AOC for making generic requests for information
Communications - “as is” - RED

- Key Commonality Parameters
  - Common frequency bands
  - Common waveforms
  - Common formats
  - Common encryption algorithms
  - Common data dissemination managers and network controllers
  - TCP / IP and UDP / IP Internet Protocols

There is no communications commonality problem that bandwidth and money can’t fix - but neither is readily available
Processor Architecture - “as is” - RED

• Shortfalls in developing a common processor architecture
  – Few common operational interfaces
  – No universal conversion standards
  – Little backward-compatibility except within family
  – No multi-level security (MLS)
  – Little common software
  – Few universal external interfaces

There is no natural, economic or legislated force driving UAV manufacturers to a common processor or to a common processing architecture

Logistics & Support - “as is” - RED

- **UAV logistics and support elements**
  - **Compatibility**: can UAV System A operate out of the same base as UAV System B?
  - **Interchangeability**: can UAV System A use the same logistics resources as UAV System B?
  - **Interoperability**: Can UAV System A perform mission planning, launch, servicing, recovery and C2 elements of UAV System B?
  - **Commonality**: Can UAV System A and UAV System B have common elements?

There is no natural, economic or legislated force driving UAV manufacturers toward logistics or support commonality.
“TO BE”
UAV Interoperability Architecture **OV-1** “to be” Vision

“Universal Interoperability” – The ability to perform Mission Planning, Launch, Command & Control, Recovery, and Servicing of any UAV System

- Complete UAV Interoperability
- Network-Centric Operations
- Coordinated Operations to Enhance GSTF Effectiveness

Concept of Operations - “to be”

“Universal Interoperability” – The ability to perform Mission Planning, Launch, Command & Control, Recovery, and Servicing of any UAV System

Common Launch / Recovery Systems

Common Training

Common Maintenance Environment
- Facilities
- Supply and Provisioning
- Support Equipment
- Technical Data / Pubs
- Integrated Vehicle Health Management

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Logistics Support and Training – “to be”

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Class IV/V IETM Tech Data
Centralized Data Repository

Common UAV Accession Training
Common UAV AFSC

Two Level Maintenance
Robust, On-Board IVHM
Std PMA/PDA Interface to AV

Common GSE
Common Hand Tools
Common AV SE Interfaces

Autonomic Logistics-Like Connectivity
to Support Info Infrastructure

Remote Mission Planning
Wireless Mission Loading
Compatible with Mx Info Infrastructure

Commonality Scorecard “to be”

<table>
<thead>
<tr>
<th>Technology Culture</th>
<th>Risk</th>
<th>Value of Commonality</th>
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- CONOPS / Operational Interfaces
- Human Systems Integration
- Mission Planning (JMPS)
- Air Vehicle C2 Interfaces
- Payload C2 Interfaces
- Communications (MP-CDL)
- Processor Architecture
- Logistics and Support

UAV architecture commonality requires direction, CONOPS, time and money
Commonality **Initiatives** Already Underway

- DoD (C4ISR) Architecture Framework (DoDAF) and Joint Technical Architecture (JTA)
- Tactical Control System (TCS), STANAG 4507, STANAG 4586
- CDL and MP-CDL
- Joint Mission Planning System (JMPS)
- E-10A (MC2A)
- AT-AOC, CAOC, DCGS, DJC2
- Transformational Communications System (TCS)
- DoD OSD UAV Interoperability IPT
  - AIAA UAV Study
  - AUVSI Study
  - UNITE / Access 5 (working National Airspace System Integration)

- Initiatives addressed in this study

**UAV commonality initiatives are incomplete and contradictory**

CONOPS / Operational Interfaces - “to be” - YELLOW

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**Missions**
I&W, IPB, Strike, BDA,
Re-supply, Comms Relay

**Launch, Recovery,**
**Mission Planning & Control**
Airborne or Ground,
LOS or BLOS,
Remote or @ AOC

**Battle Management & C2**

**UAV Control / Interface Segment**

**Exploitation & Dissemination**
Remotely Piloted, or
Automatic & Autonomous

**Air Vehicles**

**Strategic Planning**
Air Battle Planning
Reporting
Analysis

**Task, Process, Post, Use**
Human Systems Integration (HSI) - “to be” - YELLOW

Commonality

- Operators
- C2 Levels I to V
- Maps
- Status Interface
- Tasking Interface
- Voice Communications
- Common Operating Picture (COP)
- Planning

Group present and future UAVs by level of autonomy – save money and improve HSI
HSI - C2 Levels I to V - “to be”

NDIA Common UAV Architecture Study

- **Systems Evolution**
  - Air Vehicle C2 will evolve to mission following / mission management
  - In near-term, only Launch & Recovery and payload control will be operator-intensive - even that will evolve behind automation
  - Standardization of C2, SA and tasking data / displays

- **Technology Evolution**
  - Automated Operator Aids and Decision Aids
  - On-board, autonomous functionality and built-in test

- **Commonality Focus**
  - Common mission-following / management displays

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**LEVEL I**
- Secondary Product

**LEVEL II**
- Direct Data receipt

**LEVEL III**
- Payload Control
- Direct Data Receipt

**LEVEL IV**
- Flight Control
- Payload Control
- Direct Data Receipt

**LEVEL V**
- Launch & Recovery
- Flight Control
- Payload Control
- Direct Data Receipt
HSI - Autonomous Control Levels (ACL)

Fully Autonomous Swarms 10
Group Strategic Goals 9
Distributed Control 8
Group Tactical Goals 7
Group Tactical Plan 6
Group Coordination 5
On-Board Route Re Plan 4
Adapt to Failures & Flight Conditions 3
Real Time Health Diagnosis 2
Remotely Guided 1

Team of Teams
Teams
Single UAV

AFRL ACL as shown in UAV Roadmap 2000

Integration in DCGS Network

DCGS will be the AOC’s interface to the UAV Architecture

This is not rocket science but it will take determination and incentives.
### NEAR-TERM FOCUS AREAS

- Technical Publications and Technical Data
- Manpower & Training
- Maintenance
- Mission Planning Capability Support
- Integrated Vehicle Health Management (IVHM)
- Support Equipment

Feasibility = Likelihood of Occurrence Given Real Constraints (e.g., technology, political)
Value = Real Value to Customer (e.g., reduced TOC, improved war-fighting capability)
CONCLUSIONS
AND
RECOMMENDATIONS
Conclusions

Universal interoperability of UAV systems is feasible but will not be affordable unless managed properly.

Most of the architecture requirements for UAV commonality are being defined today but compliance is not being mandated.

UAV stovepipes are the biggest barriers to joint, interoperable systems, but new standards and tools will help break down cultural mindsets, organizational turf, and industry point solutions.

Industry commitment to UAV commonality is consistent with AF/XI’s goal to improve warfighting performance, but industry cannot support that commitment without government intervention.
Universal Interoperability - Conclusions

- Universal interoperability must be managed properly
- Need **enduring support** for commonality
  - Embedded in acquisition guidance
  - Funded in Service programs
  - Supported by OSD
  - Sustained in program office and HQ budget reviews
- **Realistic phasing** depends upon UAV maturity
  - Legacy Systems are virtually **impossible**
  - Block Changes can expect **modest** improvements
  - New Programs offer the greatest **potential**
- Commonality initiatives must appeal to **smaller systems** or they will opt out
- **Beyond the Air Force**, other Services, Agencies, and our Allies will benefit
- Commonality will make it much easier to develop standards **beyond UAVs**
Universal Interoperability - Recommendations

- Impose **escalating** commonality requirements ASAP
  - Procedural, training and **cultural** changes for **legacy** programs
  - **Reward** early implementation for **block upgrades**
  - **Mandatory** commonality for **new programs**

- Make new systems flexible enough to accommodate **uncertain futures**
  - Cross-program CONUS, in-theater, airborne, ship, and portable control nodes
  - Integrated UAV control functionality in BMC2 and exploitation cells
  - Multiple UAV types, quantities, payloads

- Protect the **smaller systems** – **scale** commonality requirements
  - Basic flight (“stick and rudder”) to advanced (reactive maneuver)
  - Across levels of autonomy (Level I through Level V)

- Make a single office the lead for interoperability **for all of DoD**
  - Use Air Force standards that can be used by others
  - Support the OSD UAV Interoperability IPT
  - Support OSD in enforcing interoperability standards

- Extend UAV commonality standards to all **unmanned systems**, not just UAVs
Architecture Requirements - Conclusions

- Mandate compliance with UAV commonality requirements
- Need over-arching, AF-wide UAV CONOPS - AF/XI, AFC2ISRC task
- Today’s HSI systems provide ample opportunity for commonality
- JMAPS can adjust as new systems come on line
- The Air Vehicle C2 interface can be improved
- A layered JBI-based architecture improves information exchange and separates Payload C2 from transportation and hardware layers
- Processor architectures with open, modular systems and commercial standards can help a ground station host many UAV systems
- The MP-CDL network-centric ISR comm link is compatible with E-10A, NCCT, the GIG and other programs
- Now is the time to define a common logistics and support architecture

It will only get harder as more systems come on line
• Build a CONOPS for a **universal ground station** – inherent flexibility for configuration uncertainty, payload diversity, network centricity, architecture growth
• Develop **hardware-independent software** – use open hardware / software architectures, standards and COTS products
• **Blend HSI** – standardize ground systems’ displays, data types and COP/SA requirements – reduce training and move toward multi-UAV control systems
• Transition UAV **mission planning** systems to JMPS when it is ready for fielding
• The **Air Vehicle C2** interface should meet AOC C2 requirements, be STANAG 4586-compliant, and allow for increased autonomy
• Standardize **Payload C2** request procedures in the AOC
• Use MP-CDL for **comm** for unmanned ISR systems – confirm utility for UCAV
• Develop a DCGS-compatible, PC-based **processor architecture** to host multiple UAVs in a single ground station
• Pursue **logistics** initiatives for legacy systems, block changes, and new programs
UAV Stovepipes - Conclusions

• New standards and tools will break down stovepipes, cultural mindsets, organizational turf and industry point solutions

• Organizational resistance to change is easily the most intractable obstacle
  – Sustained top-level support is essential
• Tackle internal stovepipes
  – Use JMPS, communications, tasking, training, HSI toolsets, maps, data and CAOC standards, and approved CONOPS
• Integrate external systems as the AF moves to a GIG-based, NCW force
  – “If you aren’t connected, you won’t be in the fight.”
• The architectural advantages of commonality will eventually transcend the mandate that UAV operators be rated pilots
UAV Stovepipes - Recommendations

- Designate a single office to be “in charge” of mandating commonality within DoD UAV programs
  - Give one person the budget authority to enforce commonality standards
- Impose financial stovepiping disincentives throughout the development, acquisition, manufacturing, operations and sustainment process
- Task the JROC and DAB to disapprove any UAV program that does not pass the commonality test
- Incorporate UAV operations in all phases of Joint warfighting, including operational planning, CONOPS development, training, exercises and deployment
Industry Commitment - Conclusions

• Industry cannot support architecture commonality without government intervention

• Industry is eager to partner commonality initiatives as directed by the government

• In the absence of strong industry incentives to do so, the benefits do not in themselves justify corporate commitment to commonality at the expense of corporate proprietary information

“A bird in the hand is worth two in the bush.”
Industry Commitment - Recommendations

- Make UAV architecture requirements available to industry as early in concept development as possible
  - **Use industry as a partner** in developing the best architecture for the warfighter
- Understand the baseline as early as possible
  - Build the flexibility in that will allow changes to be made **at the least cost**
  - **Any** change, for **any** reason, **always** costs money
- Mandate “commonality incentive” and “stovepipe disincentive” clauses throughout the procurement and acquisition process
  - Mandatory requirements in Source Selection RFIs, RFPs, SOWs, and contracts
  - Performance clauses that mandate commonality
  - Award fees that stipulate and reward counter-stovepipe behavior
  - Design specs that meet commonality and interface standards
Commonality will fundamentally *transform* UAV operations
- **Every** UAV manufacturer will be affected
- **Every** user, operator, and trainer will be affected

Everyone who sees commonality as a *threat to their turf* is going to fight this
- In the halls of the Pentagon, on the Hill, and in industry

Commonality will have to be *top-down* directed and supported
- Making things simpler - and cheaper - is not the natural order in a bureaucracy
- Somebody has to be in charge, with the authority *and resources* to do the job

Commonality is within reach, but we must *start now*
- “Pay me now, or pay me - a whole lot more - later”

This is not going to be easy, but it’s the **right** thing to do