

Considering an Accountability Chain for a Digitally-Enabled Cooperative Operating Mode

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Premise

For a **digitally enabled cooperative operating mode** to be a viable concept, there needs to be clarity regarding **accountability for separation**

- Clearly defining roles and responsibilities for increasingly automated flight can be challenging
  - **Authority** vs. **Responsibility** vs. **Accountability**

- Accountability is increasingly a focus of concern with stakeholders

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Authority, Responsibility, and Accountability

AUTHORITY

The power to give orders and/or make decisions.

RESPONSIBILITY

The obligation or duty to carry forward an assigned task to its successful conclusion; this is closely coupled to the authority.

ACCOUNTABILITY[1]

The obligation to answer for an action taken by a responsible entity

- **Today**: Automation has limited authority and responsibility
  - Revokable by the human
- **Future**: Envisioning significantly greater responsibility and authority of automation to make decisions and act, as delegated by humans

Premise: Accountability can only reside with a human or human-based organizational entity


ASTM AC377 AUTONOMY DESIGN AND OPERATIONS IN AVIATION

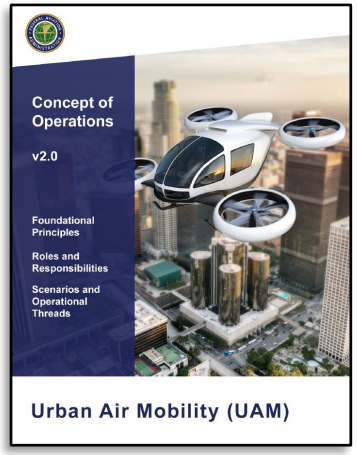
WHITE PAPER

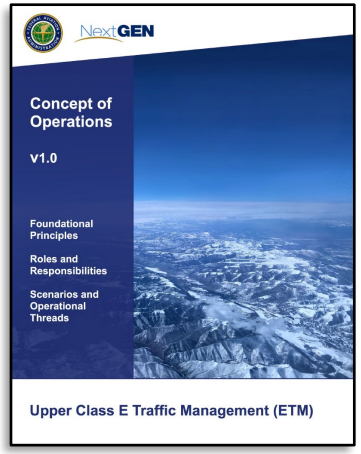
ROLES AND RESPONSIBILITIES FOR OPERATIONAL CONTROL IN THE AGE OF INCREASINGLY AUTONOMOUS FLIGHT

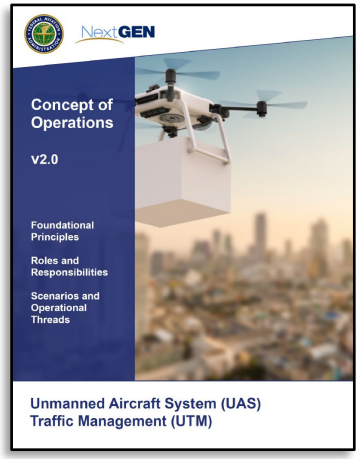
1: AC 377, Technical Report #3, "Regulatory Barriers to Autonomy in Aviation", 2022 ASTM, https://www.astm.org/tr3-eb.html

Concepts that Explore Shifts in Roles for Conflict Management

eXtensible Traffic Management (XTM)











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Commonalities

- Operator responsibility for conflict management
- Shared information
- Automated decision-making
- Cooperative operating practices

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What is an Operating Mode?

Regulatory, procedural, and technical means for aircraft to *operate safely* within the airspace

aka "*flight rules*" as defined in regulations, policies, procedures, training materials, …

Routine Operating Modes

Widespread use in most airspace classes
Routine for pilots & controllers

- Visual Flight Rules (VFR)
- Instrument Flight Rules (IFR)

Specialized Operating Modes

Limited to certain operations and/or airspace incompatible with VFR & IFR
Routine for pilots who use them; Nonroutine for controllers and other pilots

- State/Military Aircraft
- Moored Balloons / Kites / Amateur Rockets / Unmanned Free Balloons
- Ultralight Vehicles
- Parachute Operations
- Small Unmanned Aircraft Systems

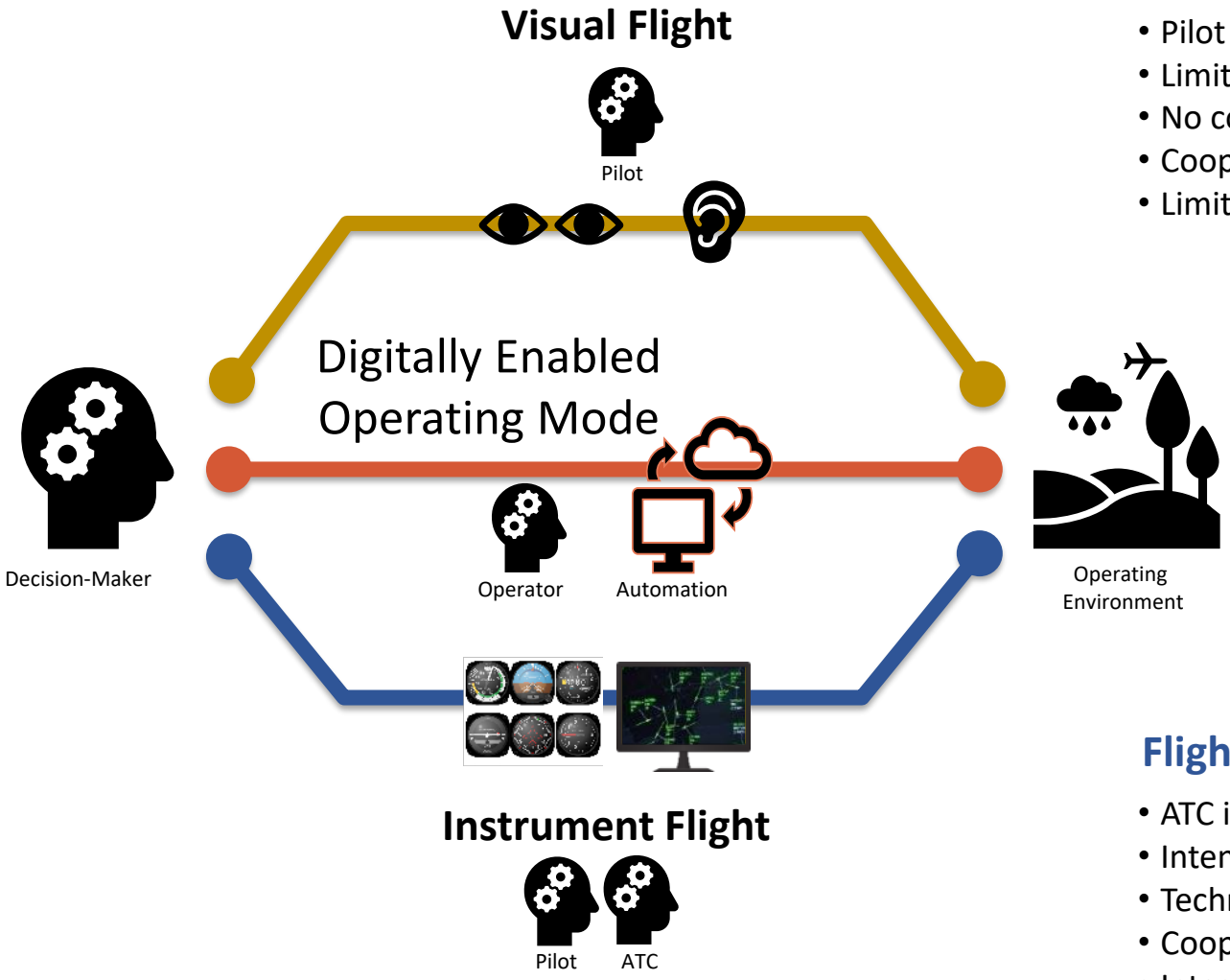
Key Points:

All flights must have an operating mode (safety requirement)

Existing operating modes depend on human situation awareness and procedures

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NASA is Exploring: Digitally-Enabled Cooperative Operating Mode



Flight by Reference to Visual Cues

- Pilot is the separator (see and avoid)
- Limited to no intent sharing
- No conflict management technology required
- Cooperative through human interpretation & judgment
- Limited to no dependence on traffic management services

Flight by Reference to Digital Capabilities

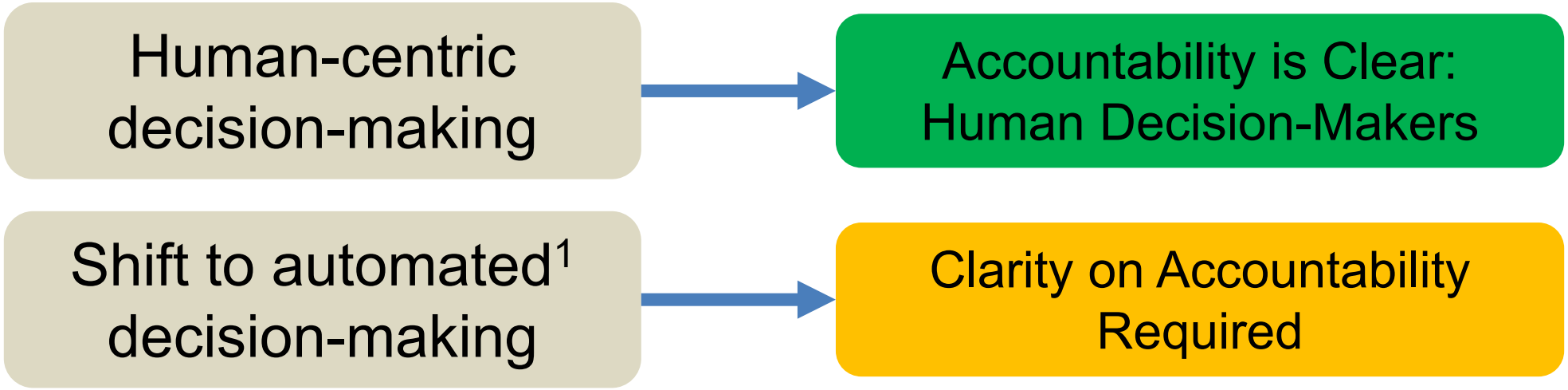
- Operator is the separator
- Required intent sharing
- Automation-dependent conflict management
- Encoded cooperative practices
- Collaborative with traffic management services

Flight by Reference to Instruments and ATC Services

- ATC is the separator
- Intent sharing with ATC, not with other IFRs
- Technology enabled, human-centered conflict management
- Cooperation through centralized control
- Integrated with traffic management services

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Shifting Decision-Making to Automation



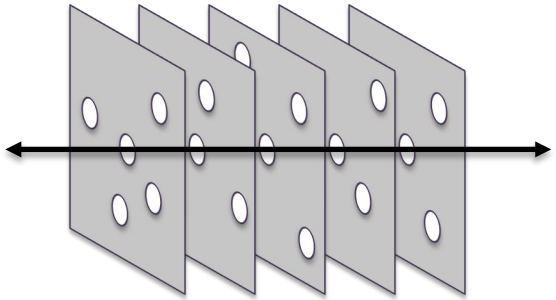
- **What's new that affects clarity**
  - Expansion of operator role in conflict management
  - Dependence upon automation
  - Conflict management when interacting with Visual & Instrument Flights
  - Dependence upon sharing operational intent
  - Dependence upon third-party information and connectivity services

1: A digitally enabled operating mode is highly dependent upon automated decision-making for separation, but the issue extends to automated/autonomous flight in general.

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Inspirations

- **Root Cause Analysis / Causal Analysis**





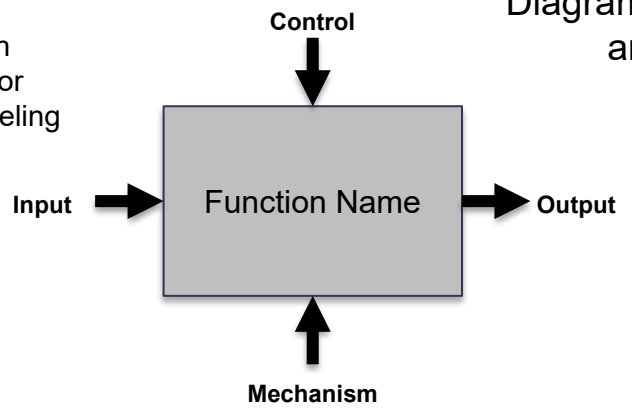
Sequencing "Chain"



Inspired by Deepwater Horizon Accident Investigation Report, September 8, 2010
https://www.sec.gov/Archives/edgar/data/313807/000119312510216268/dex993.htm

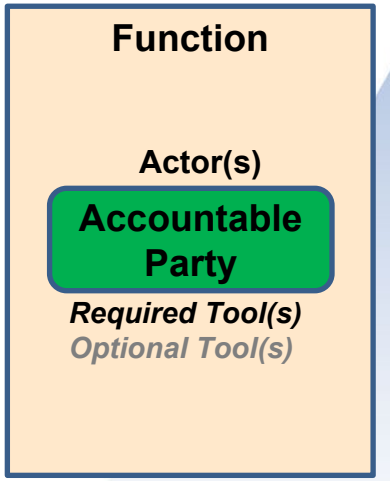
- **IDEF**
  Integration Definition for Function Modeling

Diagramming of processes and data flows



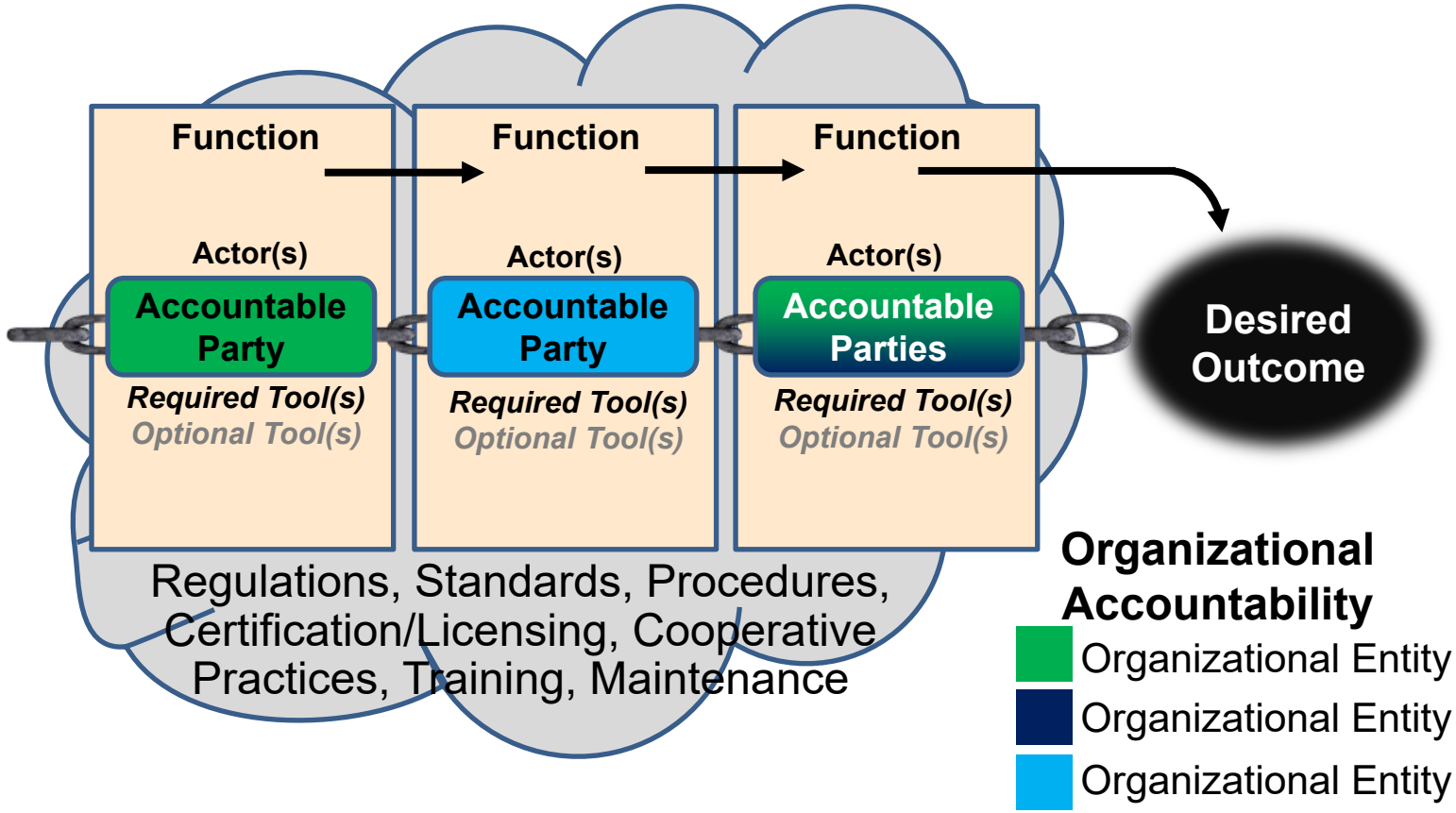


Building Block Format



Inspired by Defense Acquisition University Press, "Systems Engineering Fundamentals", Fort Belvoir, Virginia, January 2001.
https://acqnotes.com/wp-content/uploads/2017/07/DAU-Systems-Engineering-Fundamentals.pdf

Our New Model – Accountability Chain



- **Desired Outcome:** The specific result the functional process is attempting to realize
- **Functions:** Specific activities that contribute to the desired outcome
- **Actors:** The individuals or systems with the authority (power) and responsibility (obligation) to perform a function
- **Tools:** Capabilities, devices, or systems leveraged by actors to perform the function
- **Accountable Parties:** While actors are often the accountable entities, in some cases an organizational entity that manages a system may be the accountable entity.

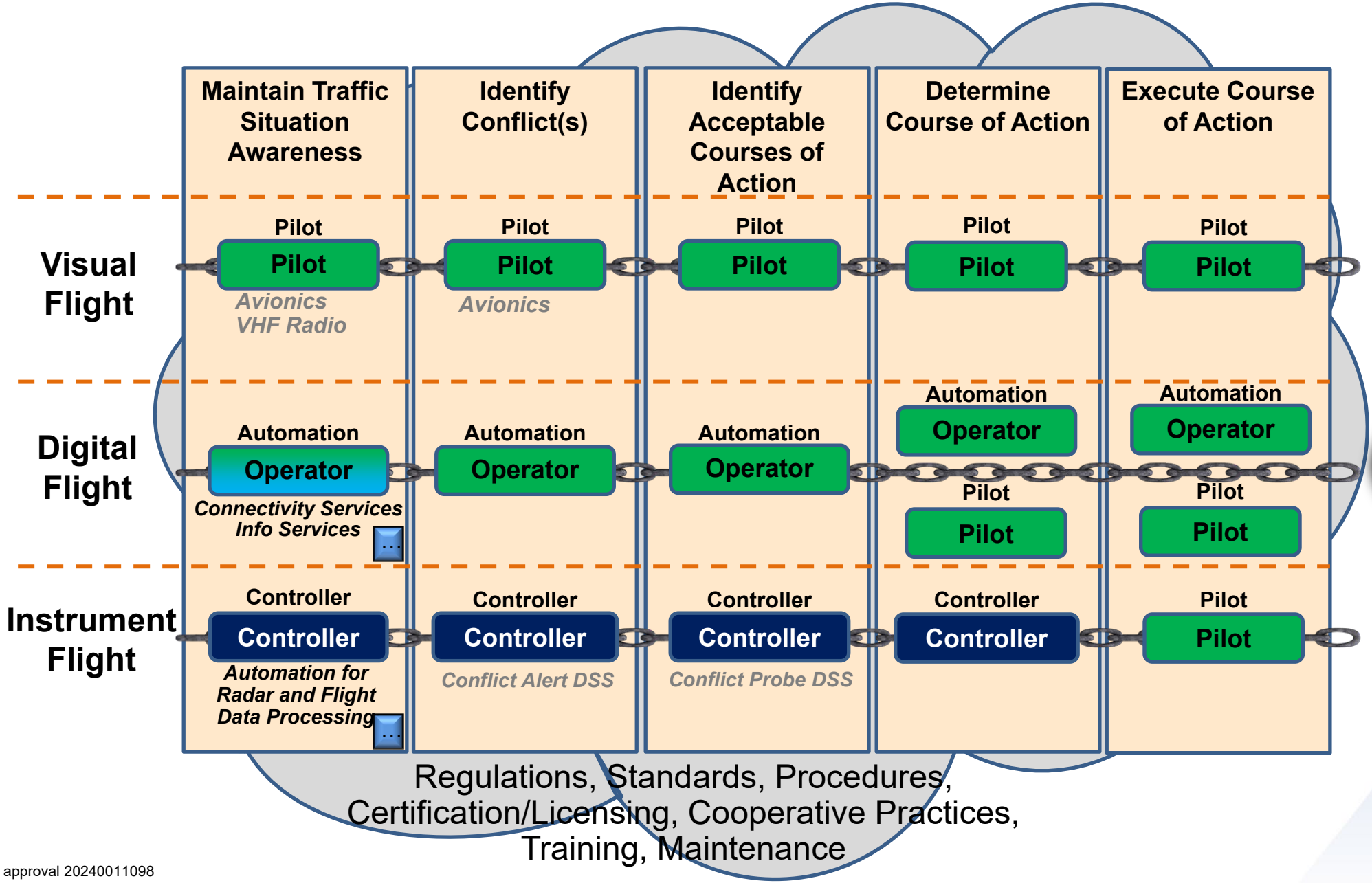
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ICAO Layers of Conflict Management

ICAO Conflict Management[1]	Visual Flight	Digital Flight	Instrument Flight (ATM Services)
Strategic Conflict Management *"Achieved through the airspace organization and management, demand and capacity balancing and traffic synchronization components; Aim to reduce the need to apply the second layer — separation provision."*	**Procedures, Practices, and Airspace Structure** • Traffic Pattern • Ordinal Altitudes • Routes, Flyways	**Traffic Flow Management & Airspace Structure** • Cooperative compliance (PC-4) • Self organization (PC-5) • Self limiting (PC-6)	**Traffic Flow Management & Airspace Structure** • Executed via ATC
Separation Provision *"Tactical process of keeping aircraft away from hazards by at least the appropriate separation minima; Only used when strategic conflict management cannot be used efficiently."*	**Remain Well Clear** Airspace user is the separator • Visual separation • May be informed by technology (e.g., CDTI, FLARM)	**Self-Separation** Airspace user is the separator adhering to defined separation minima • Operator self-separation (PC-1) • Cooperative conflict management (PC-2) • Adaptive pair-wise separation (PC-3)	**Separation Services** ATC is the separator adhering to defined separation minima • Radar separation • Procedural separation
Collision Avoidance *"Must activate when the separation mode has been compromised; Not part of separation provision; Must be compatible with separation provision mode."*	**"See" and Avoid** • Pilot vision • CDTI – Traffic Alerting • TCAS (in some cases)	**"See" and Avoid** • Pilot vision (optional) • TCAS/DAA (in all cases)	**"See" and Avoid** • Pilot vision • TCAS/DAA (in most cases)

1: International Civil Aviation Organization, ICAO Doc 9854, *Global Air Traffic Management Operational Concept*, First Edition-2005.

Accountability Chain Analysis: Separation Provision



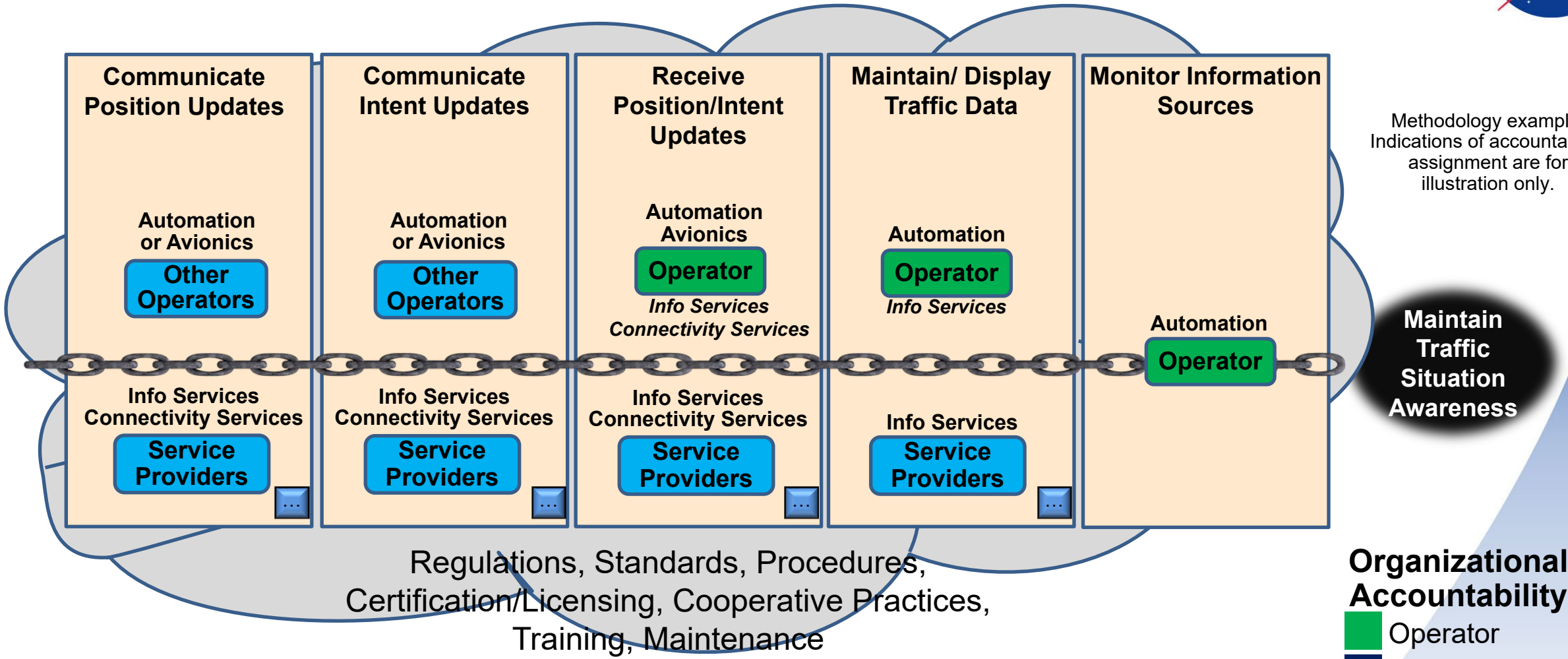
Methodology example. Indications of accountability assignment are for illustration only.

Separation is Maintained

Organizational Accountability

- Operator
- ANSP
- 3rd Party

Deeper Accountability Chain Analysis:
Maintaining Traffic Situation Awareness (Digital Operations)



Methodology example. Indications of accountability assignment are for illustration only.

Organizational Accountability

- Operator
- ANSP
- 3rd Party

Concluding Thoughts

- Is accountability a **critical barrier** to the viability of digitally-enabled cooperative operations?
- Can the barrier be **overcome**?

The *Accountability Chain* methodology could be a means to analyze and communicate accountability for increasingly automated operations in which multiple parties have interdependent roles.

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Thank You

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Backups

Detailed Framework for a Digitally Enabled Operating Mode

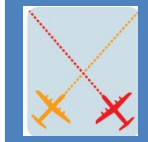
Info Services & Connectivity

Integrated Information Environment

Maintains a digital model of the operating environment for use by decision-making automation systems



Cooperative Practices



Governs the behavior of digital operations to ensure harmonized use of the airspace



Essential Elements

- Information Services & Connectivity
- Shared Traffic & Intent Awareness
- Cooperative Practices
- Automated Conflict Management Capabilities

Shared Traffic & Intent Awareness



Sharing of relevant traffic & intent information for use by automation in conflict management



Automated Capabilities



Automates the critical functions in tactical separation and strategic conflict management



Design Attributes

Safety

- Safety Benefits
- Embedded Risk Mitigations

Integration

- All Airspace Classes
- Non-Disruptive to Incumbents

Performance

- Tailorable Separation
- Aircraft Diversity

Value

- Community
- Individuals

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