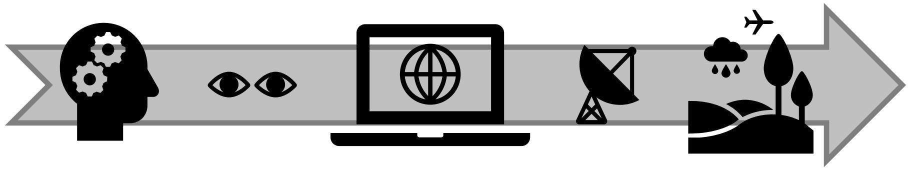


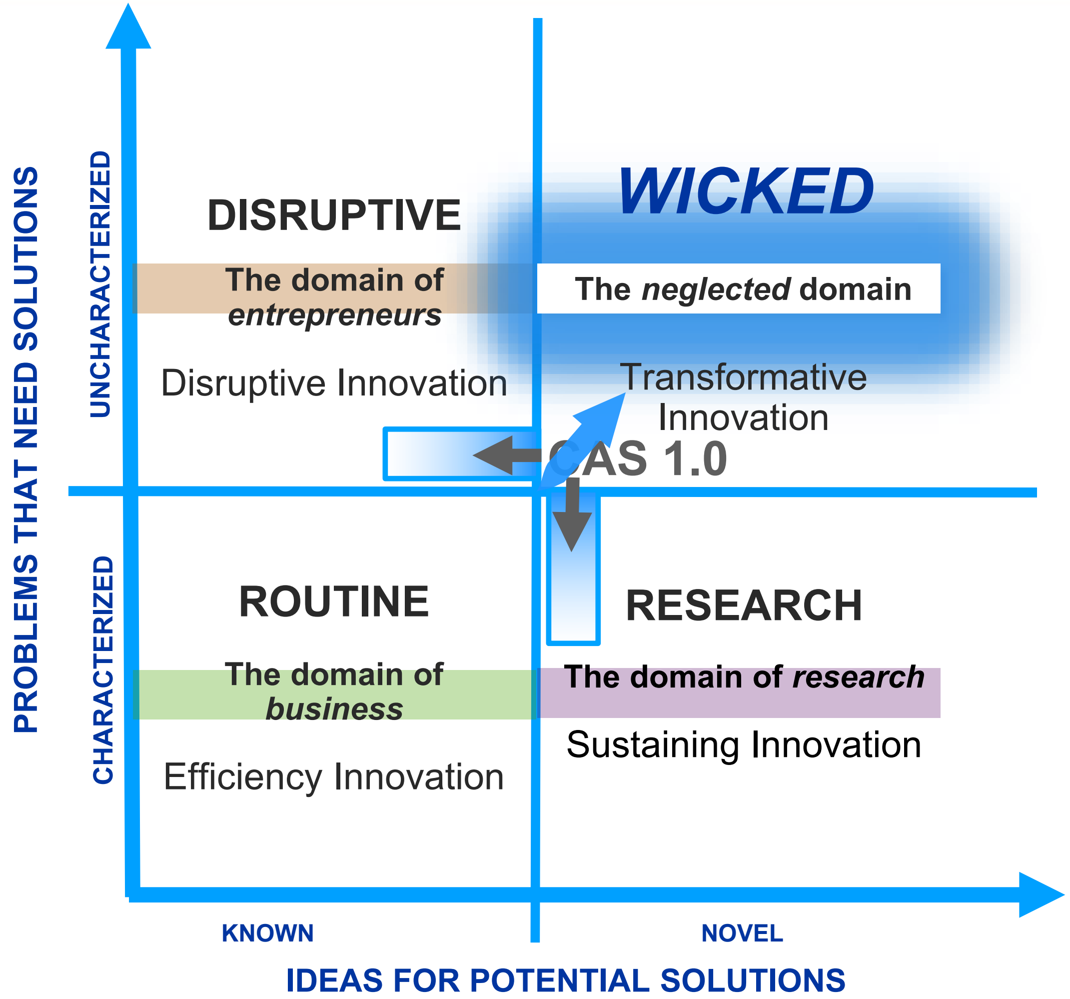
Digital Flight Workshop

PROBLEM-FOCUSED

"If I had an hour to solve a problem, I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions."

-ALBERT EINSTEIN

THE CAS CHALLENGE



Overarching Goals

- ***More* transformative**
- **Desirability, Viability, & Feasibility**

CAS Approach

- **Customer-focused**
- **Problem-focused, open aperture**
- **Asynchronous agility**

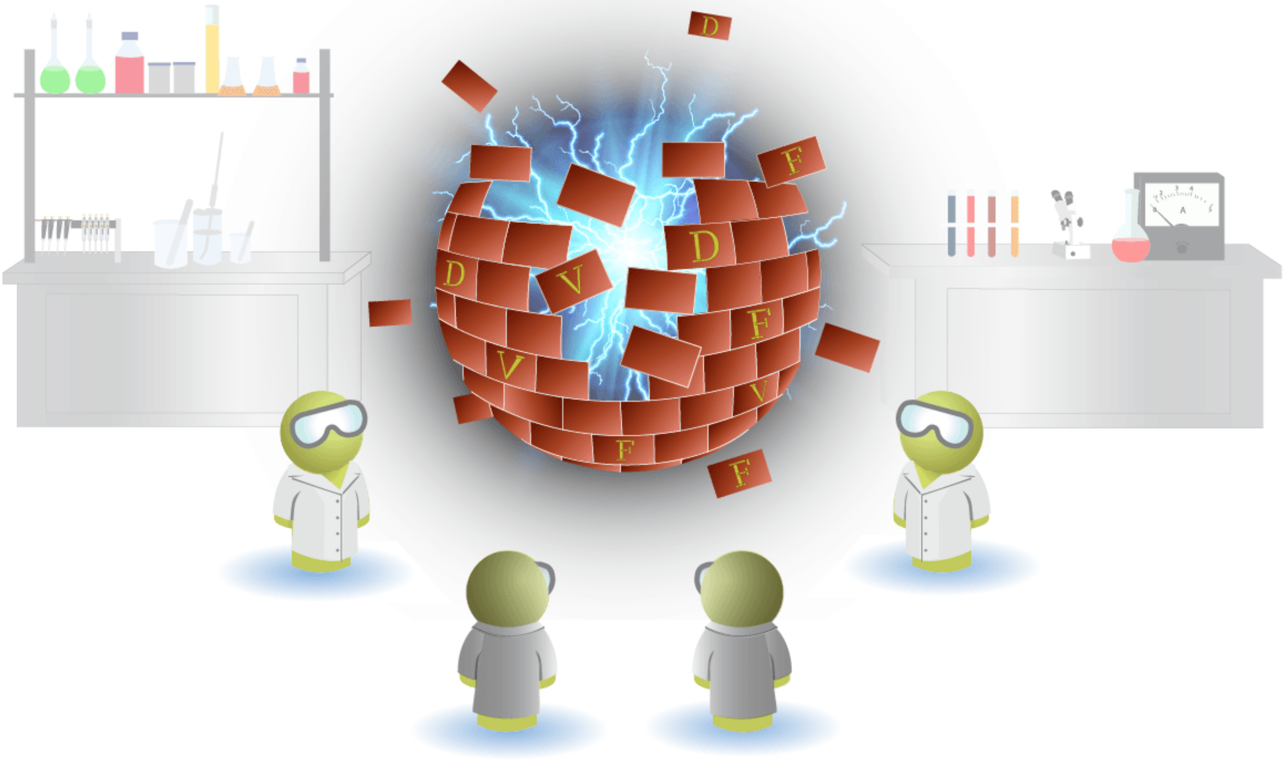
Finding Wicked Problems to Solve!

OPPORTUNITIES AS EXPERIMENTS

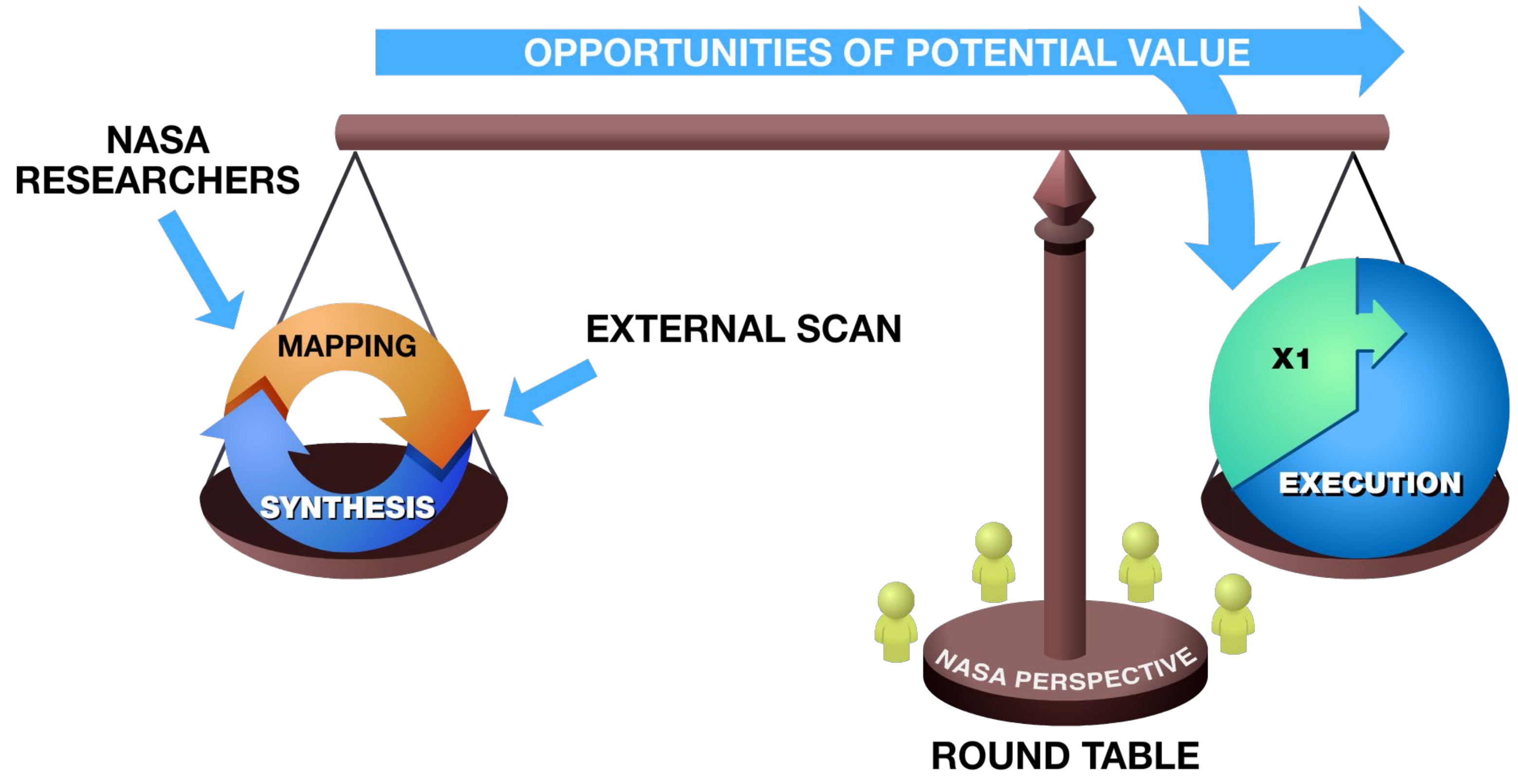
Rapid exploration of opportunities, testing Desirability, Viability, and Feasibility

CAS Scientific Method

- **Identify barriers within an opportunity space**
- **Test barriers against D, V, and/or F**
- **Transition opportunity to internal or external stakeholders**



CAS LIFE CYCLE



PRE-EXECUTION: X1

Developing work plan, solution concept, team, etc.

Who Participates?

Thought Leader, may become PI

Forming the core team

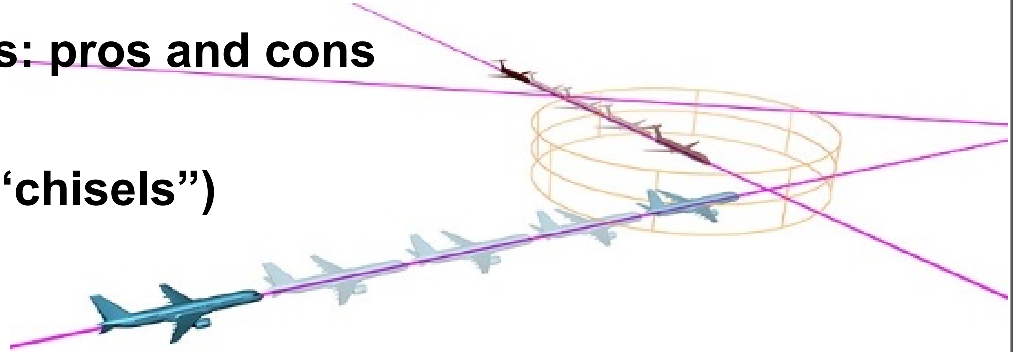
What are the Outcomes?

Progress into Execution or,

Return to Mapping / Synthesis for further probl evaluation

Digital Flight Workshop

- Workshop objectives… *Help us to:*
  - Envision potential, desirable futures… Opportunities for "Digital Flight" applicable NAS-wide
  - Explore possible scope
  - Anticipate viewpoints of operational stakeholders: pros and cons
  - Identify barriers from various perspectives
  - X1: Identify possible ways to break the barriers ("chisels")
  - Charting possible pathways forward



- Your participation
  - Bringing significant breadth and diversity of expertise
  - Representing yourself and your experience, not your organization
  - Anticipating the likely perspectives of operational stakeholder communities
  - Highly interactive sessions
  - Input will remain anonymous

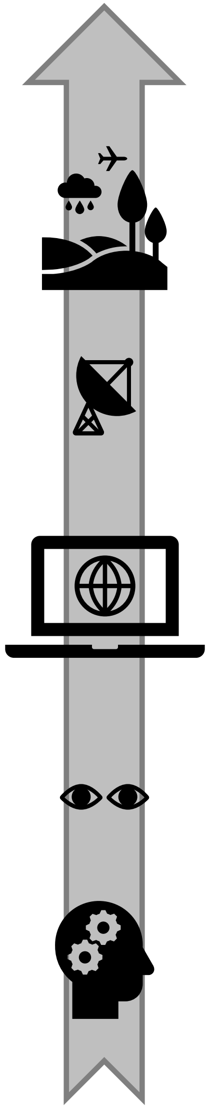
DF Workshop Plan and Schedule

Day 1: Introduction
- New capability defined
- Previous initiatives of similar scope
- Scope of Digital Flight
- Current rules analysis

Days 2-4: Perspectives
- 3 days, 3 perspectives: Users, Enablers, Protectors
- CAS analysis: desirability, viability, feasibility
- Barriers, chisels

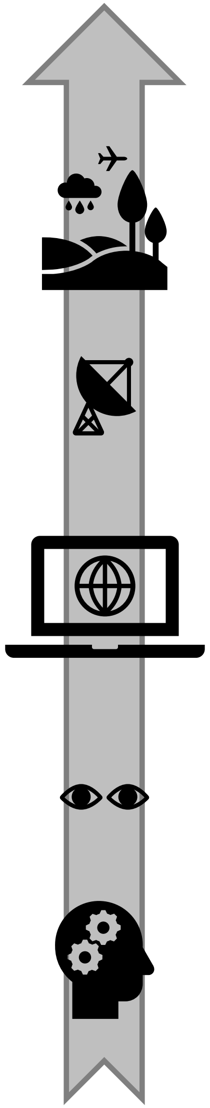
Day 5: Plenary
- Roll-up
- Other perspectives
- Recalibration
- Next steps

Day 1 Agenda



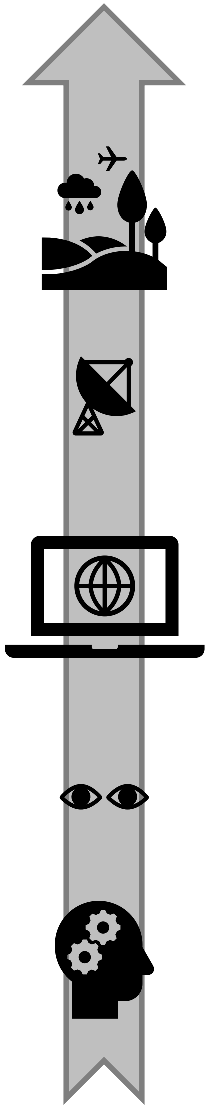
Start (ET)	Event	Speaker
12:00	Logistics	Facilitators
12:10	**Welcome / CAS Introduction**	Keith Wichman
12:20	**Briefing 1**: Digital Flight	David Wing, Ian Levitt
1:00	**Briefing 2**: Historical analysis	Bill Cotton
1:30	**Discussion**: Lessons learned	Group
2:00	BREAK	
2:15	**Briefing 3**: Digital Flight scope	David Wing
2:45	**Briefing 4**: Regulations analysis	John Maris, Paul Vajda
3:15	**Discussion**: Scope and implementation	Group
4:00	**Guest speaker** on “The Objective”	Brandon Suarez
4:15	**Briefing 5**: Breakout session preparation	Facilitators
4:30	Homework	
4:35	End of day	

Day 2-4 Agenda

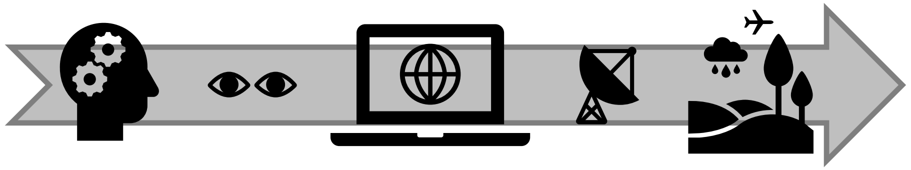


Start (ET)	Event	Speaker
12:00	**Briefing 6**: Breakout session objectives	Facilitator
12:10	**Briefing 7**: Perspective and barriers	David Wing
12:30	**Discussion**: Desirability barriers	Group
1:00	**Discussion**: Desirability chisels	Group
1:30	Break	
1:45	**Discussion**: Viability barriers	Group
2:15	**Discussion**: Viability chisels	Group
1:45	Break	
3:00	**Discussion**: Feasibility barriers	Group
3:30	**Discussion**: Feasibility chisels	Group
4:00	Homework	Facilitator
4:05	End of day	

Final Day Agenda



Start (ET)	Event	Speaker
12:00	**Briefing 8**: Breakout results summary	Facilitator
12:20	**Discussion** – stakeholders to engage	Group
12:50	**Guest speaker** on “The Vision”	To be announced
1:00	**Discussion** – new standards needed	Group
1:30	**Guest speaker** on “The Application”	To be announced
1:40	**Discussion** – new services needed	Group
2:10	**Guest speaker** on “The Implications”	To be announced
2:20	BREAK	
2:40	**Discussion** – steps forward	Group
3:10	**Guest speaker** on “The International Relevance”	To be announced
3:20	**Discussion** – Insights, recalibration	Group
4:00	**Briefing 9**: Wrap-up / how to stay involved	Keith Wichman
4:10	Happy Hour (optional “stay after” discussion)	David / Ian
4:30	End of workshop	



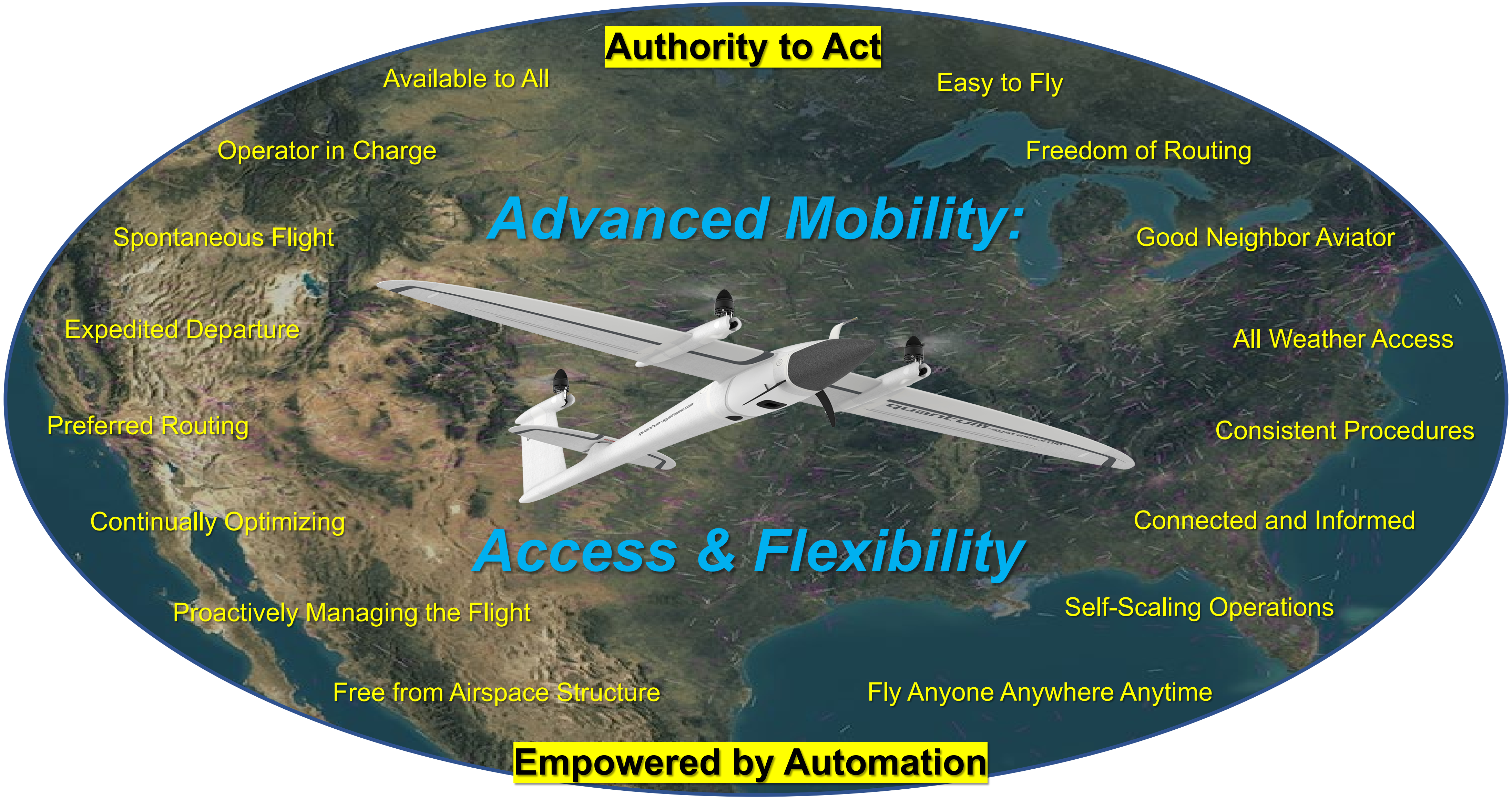
Digital Flight

Enabling the Era of Scalable Mobility in the National Airspace System

David Wing and Dr. Ian Levitt
NASA Langley Research Center

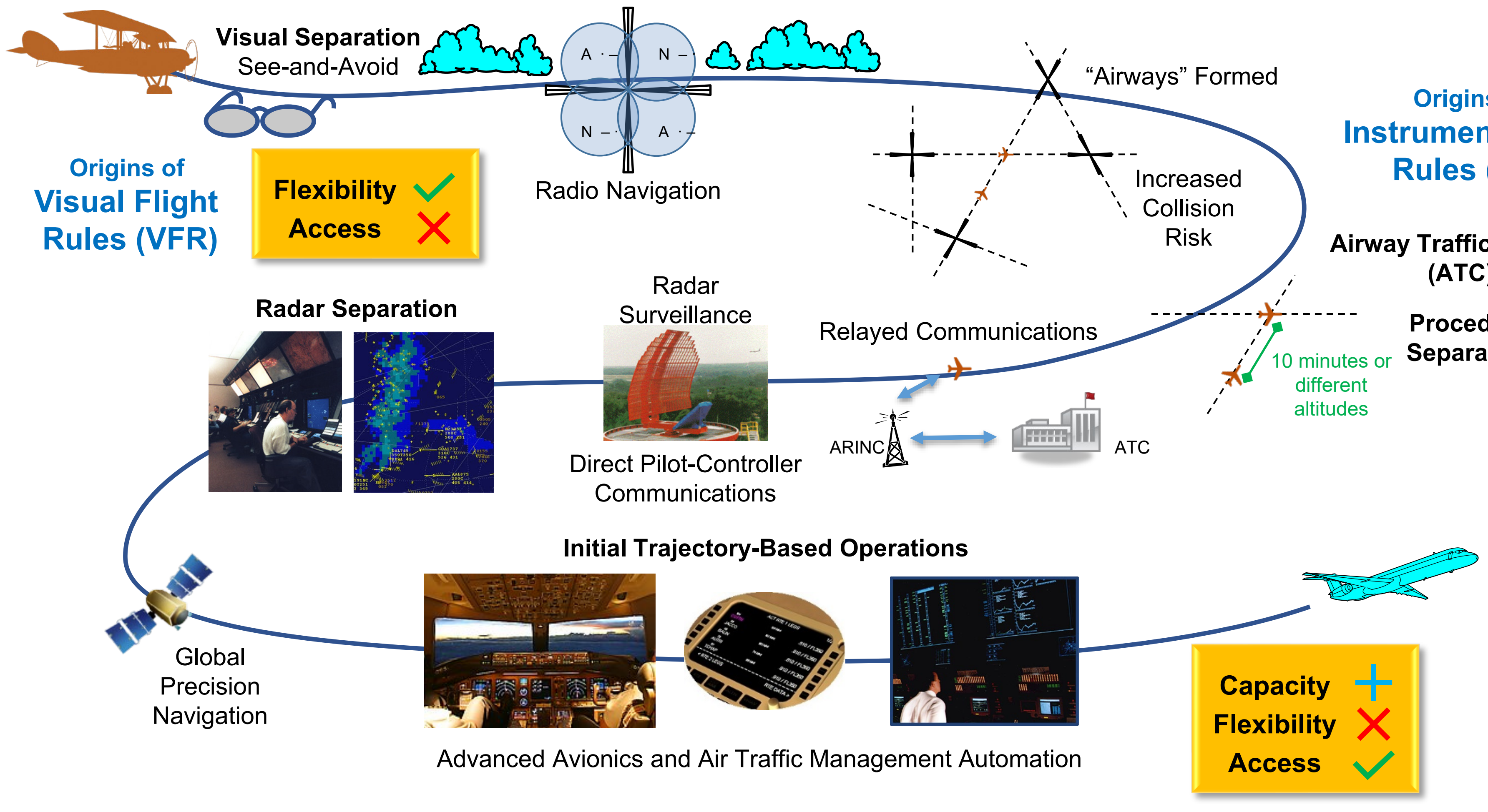
Transformational Aspiration

How Might Future Aircraft Operators Benefit from Advanced Mobility?



20th Century Evolution of Operations

Necessitated by Technologies of the Era



"New and adapted flight rules and procedures will be required to efficiently manage these increasingly dynamic operations of differing priority and types."

– "A New Digital Era of Aviation: The Path Forward for Airspace & Traffic Management," Airbus and Boeing, 2020.

Opportunity

21st Century Digital Advancements Enable Unprecedented Mobility

Digital infrastructure is emerging → Foundation for a new *digital operating mode*

	Stick & Rudder Age Mastery of Flight	**Technology Age** Connecting the World	**Digital Age** Aviation Ubiquity
Communications	Message Relay	Range-limited Voice	Satcom / Data
Navigation	Airway / Navaid	Area Navigation	Global Nav
Precision	2D Estimated	3D Bounded	4D Controlled
Surveillance	Visual / Reporting	Remote Sensing	Vehicle-to-Vehicle
Connectivity	--	Text	Broadband
Information	Charts / Eyes	NOTAMs / PIREPs	4D NAS Status
Computing	Cognition	FMS / Workstations	Net-Enabled
Prediction	Estimates	Models	Algorithms

Expect continuing and accelerating innovations and advancements

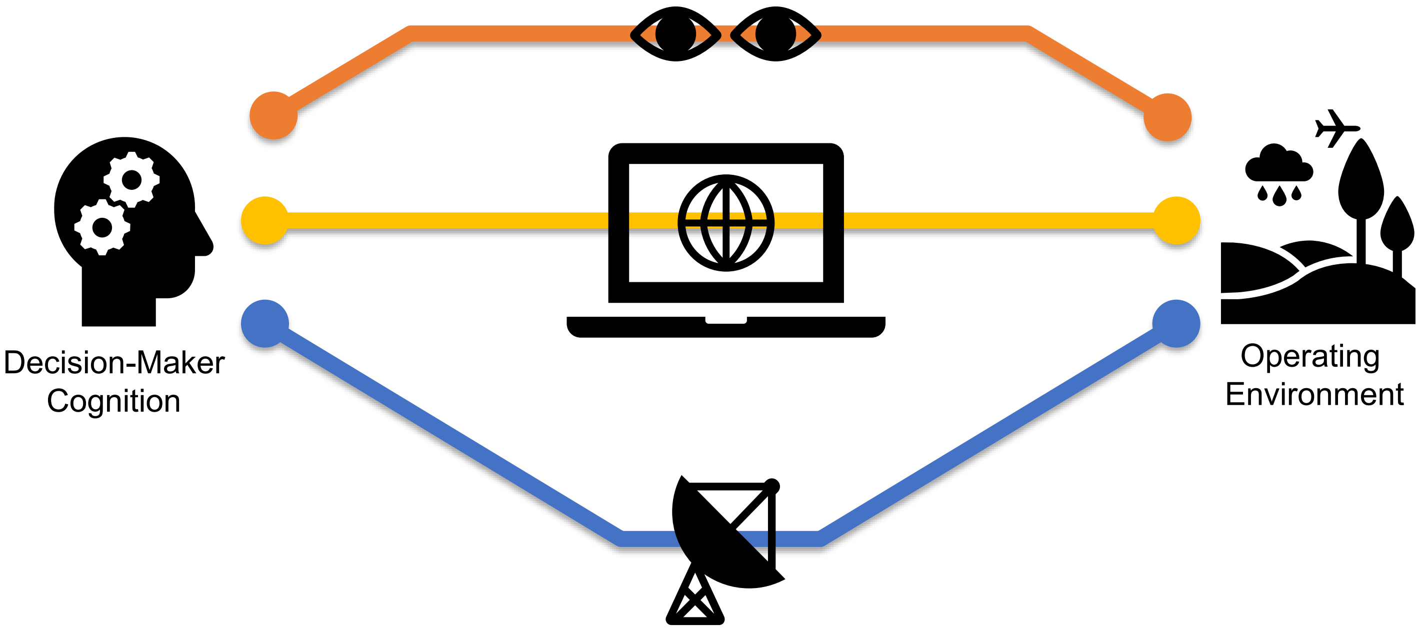
Artificial Intelligence
Machine Learning
Prognostics
Etc.

FMS	**Flight Management System**
NAS	**National Airspace System**
NOTAMs	**Notices to Airmen**
PIREPs	**Pilot Reports**

Formal Approach

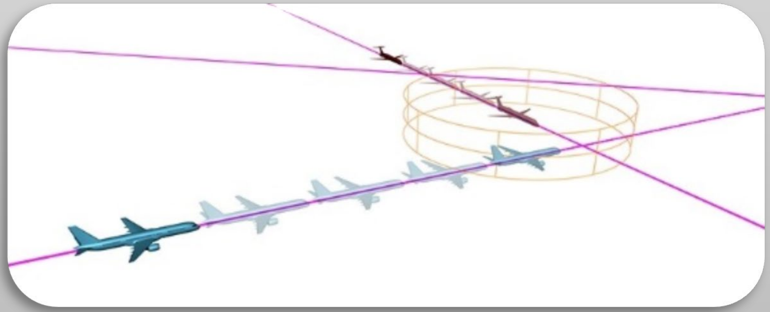
Authorizing Digital Technology-enabled Flight Operations

VFR
Perception of environment
Single decision-maker (per flight)
Allows **flexibility** but limited access



IFR
Measurement of environment
Shared decision-making
Enables **access** but reduced flexibility

Digital Flight Rules
Visual-Like Flexibility
Instrument-Like Access



Processing of environment
enabled by:
Digital connectivity
Digital information
Digital algorithms

Operator responsibility for decision-making

Beneficiaries

Unified Mechanism for All Operators to Achieve Their Mobility Vision

Digital Flight (DF)
Operational Convergence

Upper Class E Operations
"Cooperative separation"

DF could enable optimal flexibility with few restrictions

Urban Air Mobility
"M:N operations"

DF could allow UAM to outgrow segregated corridor operations

UAS Traffic Management
"Beyond visual line of sight"

DF could enable access to shared airspace above 400 ft

Regional Air Mobility
"Community-friendly regional travel"

DF could accelerate emerging markets through application of responsible technology

Large UAS
"Seamless integration"

DF could obviate lost link contingencies and maximize NAS access

General Aviation
"Simplified Vehicle Operations"

DF could reduce pilot skills & training so more people become pilots

Airline / Business Aviation
"Reduced operating costs"

DF could increase flexibility to optimize under dynamic conditions

?

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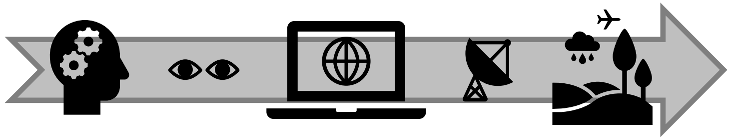
Principles for Defining Digital Flight



Principles	**Maintain Safety at Scale**	**Empower Operator Mobility**	**Minimize Impact on Ecosystem**
Implications	Employ state-of-the-art safety constructs in the operator’s role “at the edge”	Define rules that combine IFR-like access with VFR-like flexibility	Integrate and evolve with VFR & IFR
	Focus performance-based standards on safety	Authorize operators to shift reliance to self-service and third-party service providers	Minimize changes and impact to airspace operations
	Address the role of cooperative behavior among operators	Invest operator with responsibility for safety assurance	Minimize negative impacts on ATC procedures, workload, training, and staffing

Principles	**Enable Operational Diversity**	**Maintain Fairness and Equity**	**Ensure Durability and Sustainability**
Implications	Lower the barriers to operator participation through use of technology	Fairly accommodate new entrants and existing operators	Prioritize aviation safety, security, and resilience
	Introduce new operator capabilities which foster diverse and innovative applications	Incentivize community-based cooperation, contributing to the common good	Achieve simplicity where possible, while deploying complexity where necessary
	Establish a cooperative environment to encourage diversity	Ensure fairness in the marketplace	Apportion complexity across systems to enhance technical and economic viability

Some Tall Poles

Don’t lose sight of the forest for the trees!

ATC: Ensuring minimum disruption, changes, and burden on existing ATC services
VFR/IFR: Coexisting without imposing new equipage, rule changes, or restrictions
Implementation: Creating an incremental and palatable rollout structure

Automation: Certifying responsibility, developing standards, establishing reasonable means of compliance
Services: Certifying service providers, automated services, and associated data and infrastructure
Human-automation teaming: Ensuring feasible solutions (remote and onboard)

Equity: Enabling diversity through different certification levels while preserving equity
Diversity: Accommodating highly differentiated aircraft performance in same airspace

Comm: Availability of adequate comm links, budget, spectrum, and network system reliability
Infrastructure: Minimizing airspace infrastructure requirements and investments
Separation: Variable separation standards that do not reduce safety

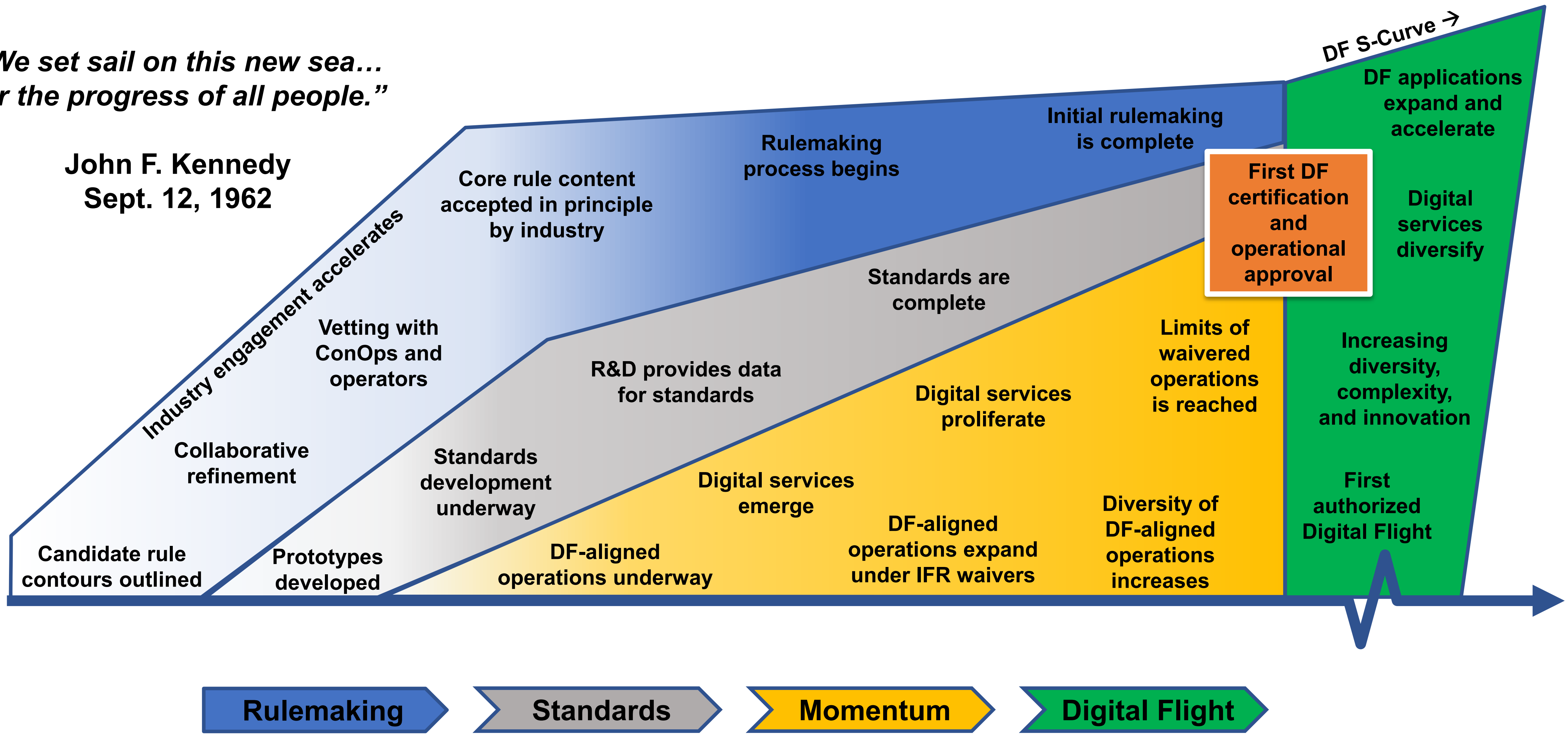
Safety: Automating resilience and productive safety (Safety II)
Disruptions: Addressing the impacts of systemic disruptions, local emergencies, and cybersecurity

Principles: Not compromising the principles and objectives of DF in accommodating <u>all users</u>

Digital Flight: A Moonshot for Aviation

*"We set sail on this new sea…
for the progress of all people."*

John F. Kennedy
Sept. 12, 1962



The Future of Aviation is Mobility

Digital Flight

- **Responsible operators** safely and flexibly share the airspace
- **Designed** for the emergent Digital Era of the airspace system
- **Convergence** will accelerate new aerial services for public benefit
- **Transformation** that will improve aviation’s contribution to society

Digital Flight

Self Directed -- Self Protected
Strategically Connected
Cooperative and Respected

NASA publication to spark a conversation about Digital Flight

Click to access this paper

NASA/TM–20205008308

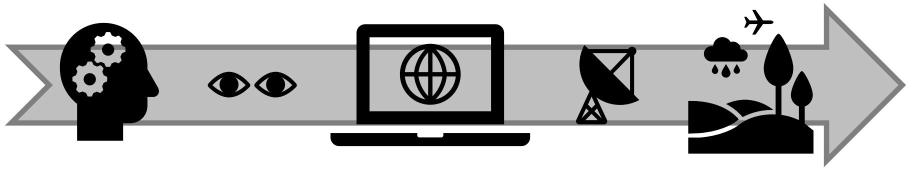
New Flight Rules to Enable the Era of Aerial Mobility in the National Airspace System

David J. Wing and Ian M. Levitt
Langley Research Center, Hampton, Virginia

We Invite Your Thoughts

What are the barriers?
How do we overcome them?
How do we make Digital Flight real?

david.wing@nasa.gov
ian.m.levitt@nasa.gov



History of Transformational NAS Technologies

William B. Cotton

NIA subcontractor
Cotton Aviation Enterprises, Inc.

Basic Tenets of NAS Technologies

- New Technologies are introduced into the NAS primarily for either:
  - Capacity and Efficiency improvement, or
  - Safety improvement, often with some overlap

- Historically, transformational technologies have required new hardware and/or software systems and associated procedures:
  - In support service systems (ground or space)
  - In the aircraft receiving those services, or
  - In both places

- Many changes have been proposed, not all have been implemented

NAS Functional Responsibility Paradigm

- VFR operations – Aircraft system responsible for all aspects of flight safety (obstacle, weather and traffic avoidance) in all class C, D, and E airspace, ATC responsible for sequencing in Class C and D, plus separation in Class B. VFR not permitted in Class A airspace.

- IFR operations
  - ATC responsible for separation among all IFR flights
  - IFR aircraft responsible for separation from VFR flights
  - IFR aircraft responsible for obstacle and hazardous weather avoidance
  - Navigation responsibility primarily in the aircraft and passed to ATC, when being radar vectored

- ATC is based on human controllers being responsible for separating IFR aircraft within their sector boundaries using primarily radar-based surveillance and VHF voice communications with human pilots in the aircraft.
  - All proposed changes are judged against that paradigm

Historic Capacity and Efficiency Proposals

System	Ground	Air	Both	Years
Cooperative surveillance (transponders)			X	20
RVSM		X		30
ARTS, AAS and ERAM	X			30+
SATCOM	Space		X	20
GNSS including GPS	Space	X		16
FANS and FANS 1/A			X	10
RNP and RNAV, enroute and approach			X	15
LAHSO	X			5
MLS			X	10 *
ADS-B			X	30
DataComm			X	40+
EFR, FreeFlight, AFR			X	50+ *
NextGen	X			15
Digital Flight			X	?

*** Indicates partial or no implementation**

Historic Safety System Proposals

System	Ground	Air	Both	Years
GPWS and EGPWS		X		5
LLWAS	X			5
Airborne windshear alert		X		3
TCAS (after ACAS, BCAS, LCAS and KCAS)		X		40
TAWS		X		3
Wake Vortex Advisory System	X			10 *
SVS and EVS		X		35
HUD		X		45
Digital Flight			X	?

*** Indicates partial or no implementation**

Factors Leading to Successful Implementation

- Strong Business Case
- Strong Advocacy by Industry or Government Champion
- Clear, proven technical solution
- International cooperation and commitment
- FAA Mandate
- Congressional Action – passing a law
- Investment commitment by proponent

Barriers to Success

- Cost to users, for airborne equipment and training
- No, or inadequate, budget for service providers
- Immature technology or competing alternatives
- Solutions that require “critical mass” of users before benefits accrue
- FAA System for Safety Assurance
  - Certification process (especially if new system doesn’t fit existing process)
  - Operational Approval process
- Compatibility with the existing ATC paradigm
- Industrial resistance

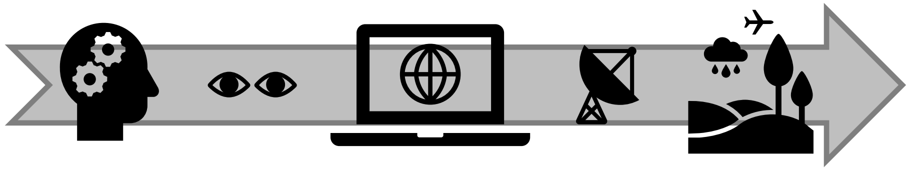
Digital Flight Design

- Designed for safety in IMC from:
  - Obstacles
  - Weather hazards
  - Traffic

  While:
  - Operating on optimized flight trajectories
  - Compatible with VFR and IFR traffic in the same airspace
  - Cooperating in TFM initiatives, runway use management
- Designed to have a strong business case
- Designed to be certifiable by using mature technologies
- Designed to overcome barriers to success
  - Benefits to first user
  - Right of Way to IFR and VFR
  - ATC aware but not responsible

Next Steps

- Study the lessons of history, learn from them
- Seek high level champions for Digital Flight in Industry and Government
- Seek counsel and input from each user community on ways to proceed
- Coordinate multi-organizational development and implementation efforts to overcome barriers as they arise



Digital Flight Scope

An Opening Bid for Formalizing Digital Flight

DF Operator Privilege

The DF operator may operate in all airspace classes and flight visibility conditions, while always retaining full responsibility for safety.

Access

The DF operator may operate in all airspace classes in VMC and IMC without specific clearance from ATC.

Flexibility

The DF operator may alter the aircraft's flight path without specific clearance from ATC.

Automation Reliance

The DF operator may rely on certified "responsible" automation in the execution of their responsibilities.

Service Provision

The DF operator may self-serve or employ authorized providers of services to meet their responsibilities.

DF Operator Responsibility

The DF operator is responsible for protecting the aircraft's flight path from all safety hazards in all flight visibility conditions.

Navigation Responsibility

The DF operator shall manage the aircraft's flight path to ensure flight safety and adherence to airspace constraints.

Separation Responsibility

The DF operator shall manage the aircraft's flight path to ensure separation from all traffic including mixed operations.

Digital Technology Use

The DF operator shall employ certified digital automation connected to appropriate authorized data sources.

Cooperative Rules, Standards, or Best Practices

- Be predictable
- Share your intent and keep it current
- Don't create conflicts for others to solve
- Give right-of-way when it is due
- Coordinate maneuvers when appropriate

Separation Standards
Timing Standards
Comm. Standards

Right-of-Way Rules
Coordination Rules
Etc.

Information Management

The DF operator shall receive, store, process, and maintain current all information, as needed to meet their responsibilities.

Flight Path Prediction

The DF operator shall maintain a current digital prediction of the intended flight path and the conformance tolerance.

Cooperative Operations

The DF operator shall conduct cooperative operations including sharing the aircraft's intended flight path and coordinate appropriately.

Beneficiaries

Unified Mechanism for All Operators to Achieve Their Mobility Vision

Upper Class E Operations
"Cooperative separation"

DF could enable optimal flexibility with few restrictions

?

Urban Air Mobility
"M:N operations"

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?

Scope – What the Digital Flight Vision IS

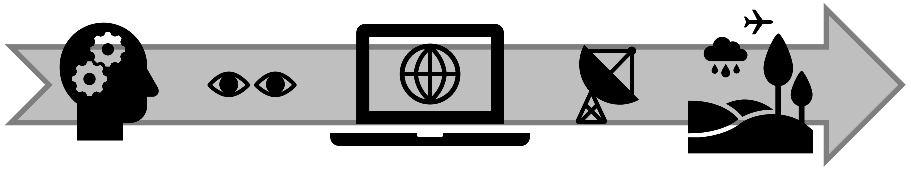
- A new flight mode
  - Combining some of the best attributes of VFR and IFR
  - Employing technology to overcome some of the limitations of VFR and IFR
- A sustained flight authorization
  - Persistent from take-off to landing (unless operator switches to VFR or IFR)
  - Established by operator “filing a DF flight plan” or some similar declaration
- A capability founded on safety-critical digital connectivity, information, and automation
  - Visual and standard instrument systems and procedures won’t be enough
  - May leverage visual & instrument procedures in certain conditions
- Defined broadly and generally enough to enable diverse applications
  - Can be invoked for various purposes and benefits in different operational domains
  - Can have a variety of performance levels to suit operational need and risks
  - Applicable to all operations (smallest to largest; slowest to fastest; piloted to fully automated)
- Far reaching and sustainable to meet future needs
  - In UAM terms, compatible with UML-5&6

Scope – What the Digital Flight Vision Is <u>NOT</u>

- Not a replacement or displacement of existing flight modes
  - DF complements VFR and IFR as a third alternative with unique attributes
  - DF shares the airspace equitably and cooperatively
- Not a “Concept of Operations” of its own
  - DF is intended to integrate with – and enable – emerging and existing concepts
- Not a complete system design
  - DF is a “concept element” working in concert with other critical elements in the NAS
  - DF is supported by an ecosystem of connectivity, data sources, technologies, and operational rules
- Not a “delegated” procedure
  - DF is the operator’s choice and is not revokable or externally terminated during flight
- Not a free-for-all
  - DF carries responsibilities for cooperative behavior, information sharing, and safety assurance
  - DF collaborative capabilities may facilitate traffic complexity and flow management
- Not a static capability
  - DF is performance-based, which allows incorporation of continuing technology advances
  - DF is a foundation for long-term innovation

Scope – What the Digital Flight Vision Could Be

- Third complementary set of Flight Rules
  - Design as desired and minimize changes to VFR, IFR
  - But must be generalized to support all types of operations
- Suite of operation-specific Flight Rules (UTM, UAM, ETM, etc.)
  - Each community defines exactly what they need
  - But creates patchwork of rules with complex interplay (or strict segregation)
- Augmented VFR
  - Update “visual” rules to include digital situation awareness and decision-making
  - But must preserve Visual Flight while accommodating significant differences of Digital Flight
- Pre-flight IFR "delegated operation" lasting the whole flight
  - Accommodates Digital Flight as an IFR clearance
  - But complicates rolls and responsibilities of pilots and controllers
- Non-flight-rule operation (like Part 107)
  - Builds on recent precedent
  - But still requires rulemaking to ensure clear responsibilities and performance requirements



Digital Flight Regulatory Gap Analysis

Dr. John Maris, Paul Vajda

NIA subcontractor

Advanced Aerospace Solutions, LLC.

Problem Statement

Objective: define a new flight mode that enables high volume operations through self separation and automated, self-organizing flow management throughout the NAS.

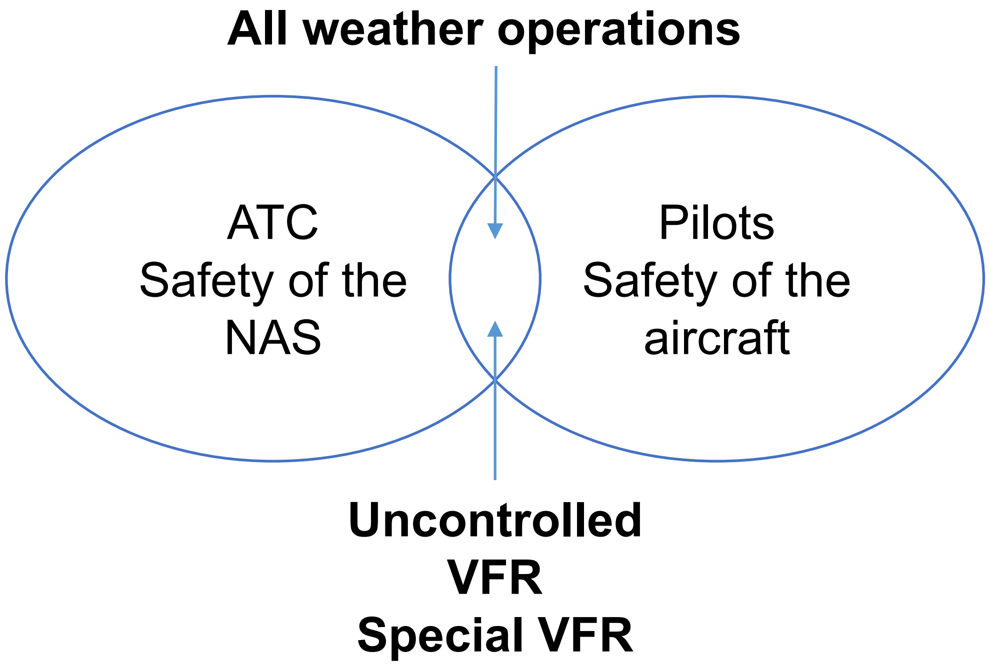
Challenge: Given the constraints imposed on accessibility and flexibility by present day flight rules and regulations, how do the former need to be modified to achieve this new chapter of aviation.

DF Tenet

Aircraft shall have authority over their trajectory in all weather conditions.

Impacts existing responsibility paradigms:

1. ATC is responsible for the safety of the airspace as a whole
2. Pilots are responsible for the safety of their aircraft



DF Tenet

All properly equipped airspace users should be able to operate under DF

- Digital Flight is "for everyone":
  - Existing aircraft
  - Remotely Piloted Aircraft
  - Autonomous Aircraft
  - sUAS
  - …

→ DF is not simply an operational innovation solely requiring new procedures

→ DF is equipment dependent

Regulatory Gap Analysis – Two Approaches

1. "What regulations impede unfettered access and flexibility for **today's** pilots and aircraft?"

   e.g.,: 91.135 Operations in Class A airspace. (a) "*Clearance.* Operations may be conducted only under an ATC clearance received prior to entering the airspace"

2. "What regulations impede unfettered access and flexibility for **tomorrow's** pilotless aircraft?"

   e.g.,: 91.3 Responsibility and authority of the pilot in command. "(a) The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft."

Current progress

1. Reviewed Parts 91, 107, 121 and 135
2. Review of Order JO 7110.65Y: Air Traffic Control procedures policy document in progress
3. Classified the regulations as:
   - No Impact
   - Rule Amendment
   - Rule Making

Current findings

1. Most regulations have no particular impact (semantically) on DF

Impact	Part 91	Part 121	Part 135	Part 107
No Impact	86%	92%	83%	85%
Rule Amendment	7%	6%	13%	15%
Rule Making	7%	2%	4%	0%

§ 91.181 Course to be flown.

Unless otherwise authorized by ATC, no person may operate an aircraft within controlled airspace under IFR except as follows:

(a) On an ATS route, along the centerline of that airway.

Current findings

2. Parts 91, 121 & 135:
   - have equipment/airworthiness requirements "baked in"
   - are prescriptive

14 CFR § 91.151 Fuel requirements for flight in VFR conditions.

(b) No person may begin a flight in a rotorcraft under VFR conditions unless (considering wind and forecast weather conditions) there is enough fuel to fly to the first point of intended landing and, assuming normal cruising speed, to fly after that for at least 20 minutes.

Current findings

3. Definitions of certain terms are assumed:
   - "two-way radio communications"

Current findings

3. Definitions of certain terms are assumed:
   - "two-way radio communications"
   - "Flight visibility"

14 CFR §1.1 Definitions

Flight visibility means the average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

Current findings

3. Definitions of certain terms are assumed:
   – “two-way radio communications”
   – “Flight visibility”

14 CFR §1.1 Definitions

Enhanced flight visibility (EFV) means the average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system.

Current findings

3. Definitions of certain terms are assumed:
   - "two-way radio communications"
   - "Flight visibility"
   - "Pilot in command"

14 CFR §1.1 Definitions

Pilot in command means the person who […]

Person means an individual, firm, partnership, corporation, company, association, joint-stock association, or governmental entity. It includes a trustee, receiver, assignee, or similar representative of any of them.

Current findings

4. DF regulations should be performance based
   – Digital Flight Visibility

§ 91.155 Basic VFR weather minimums.

Airspace	Flight visibility	Distance from clouds
Class A	Not Applicable	Not Applicable.
Class B	3 statute miles	Clear of Clouds.
Class C	3 statute miles	500 feet below.
		1,000 feet above.

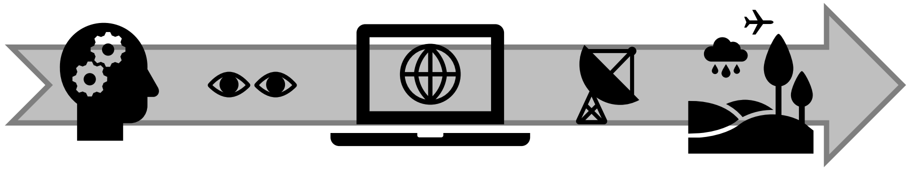
Current findings

4. DF regulations should be performance based
   - Capability Margins

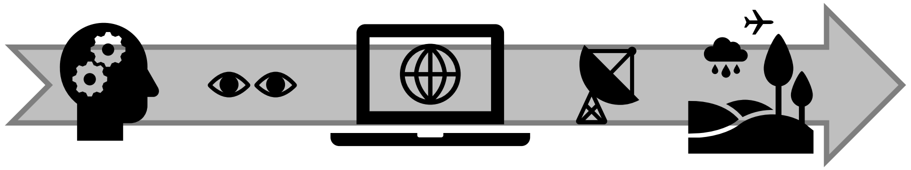
14 CFR § 121.189 Airplanes: Turbine engine powered: Takeoff limitations.
14 CFR § 91.151 Fuel requirements for flight in VFR conditions.

5. A performance based complementary set of flight rules to VFR and IFR is likely the strategy with the highest chance of success

Questions & Discussion



Guest Speaker
Brandon Suarez



Breakout Preparation

Desirability, Viability, Feasibility

- The upcoming breakout sessions will focus on the desirability, viability, and feasibility of Digital Flight.

- ***Desirability*** is “Market Desirability”, such as the public and industry demand for lowering the barriers to airspace access and increasing operational flexibility.

- ***Viability*** is “Business Viability”, such as ROI relative to equipage and compliance costs and sustainability for long-term growth.

- ***Feasibility*** is largely “Technical Feasibility”, such as automation support for safe operations, spectrum allocation for DF communications, and interoperability with the existing NAS.

Desirability, Viability, Feasibility

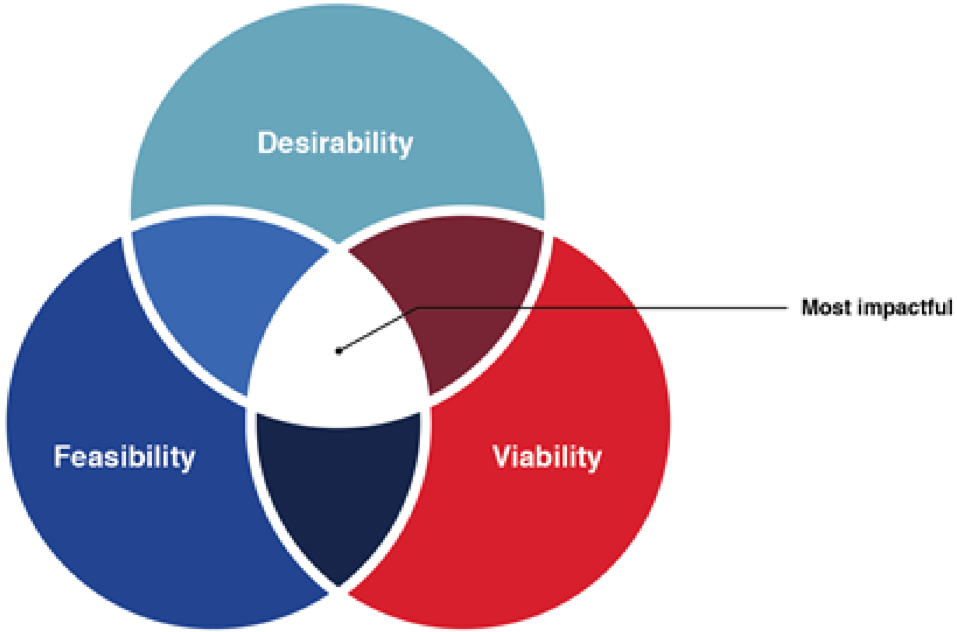
Why is this Useful?

- ***Desirability*** captures societal needs and potential value to stakeholders
- ***Viability*** captures the business path forward and considers the government role of NASA
- ***Feasibility*** captures alignment to NASA skills/capabilities

Whether or not a particular opportunity is worthy of pursuit depends on a holistic consideration of these D-V-F dimensions

Problem-Analysis

Adopting a Needs-based Perspective
Taking a Holistic, System-level View



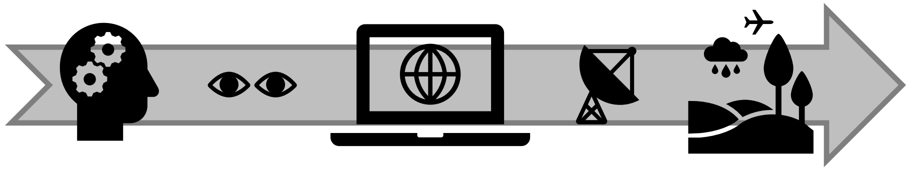
Breakout Sessions

- There will be three breakout sessions, with participants representing the perspectives of ***users, enablers, and protectors.***

- During the breakout sessions we will:
  - Identify barriers to the desirability, viability, and feasibility of Digital Flight
  - Characterize these barriers as:
    - Unbreakable (physics barriers)
    - Requiring revolutionary change (sound barriers)
    - Requiring engineering work (implementation barriers)
    - Requiring messaging and education (perception barriers)
  - Identify specific actions, or "chisels," to break down the most relevant barriers

Homework

- Start capturing thoughts on barriers and chisels
  - Barriers: impediments to DF acceptance for further consideration / investment
  - Chisels: incremental steps to help chip away at barriers to allow further consideration / investment
- Take the perspective of your breakout session (Users: Sept 8., Enablers: Sept 9., Protectors: Sept. 10.)
  - Anticipate the perspective of operational stakeholders (not just your own)
- Plan to be descriptive (more than one or two words)



Digital Flight Breakout Session

DF Workshop Plan and Schedule

- ✓ Day 1: Introduction
  - New capability defined
  - Previous initiatives of similar scope
  - Current rules analysis
  - Scope of Digital Flight

- ➢ Days 2-4: Perspectives
  - 3 days, 3 perspectives: Users, Enablers, Protectors
  - CAS analysis: desirability, viability, feasibility
  - Barriers, chisels

- Day 5: Plenary
  - Roll-up
  - Other perspectives
  - Recalibration
  - Next steps

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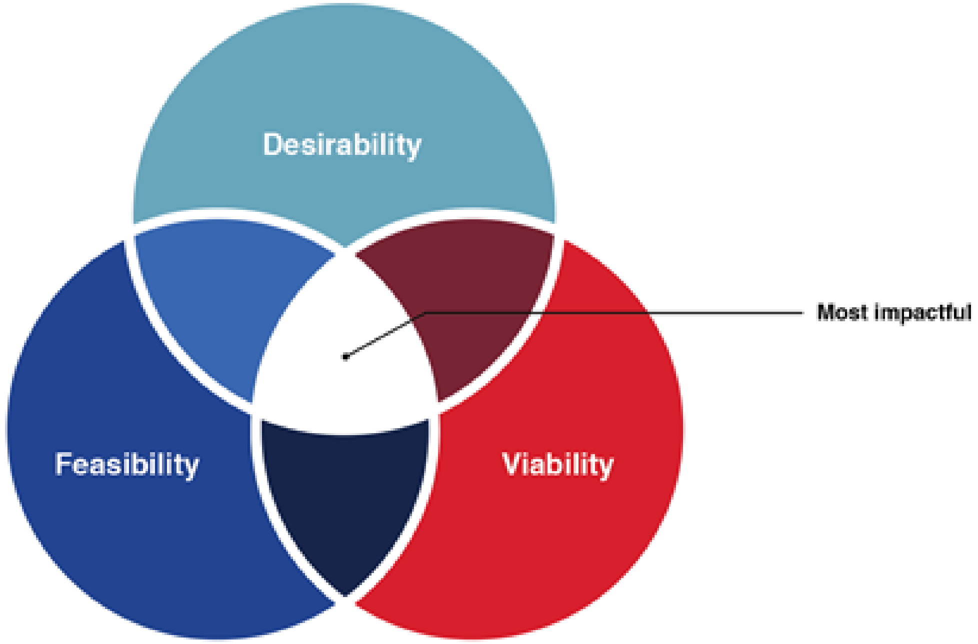
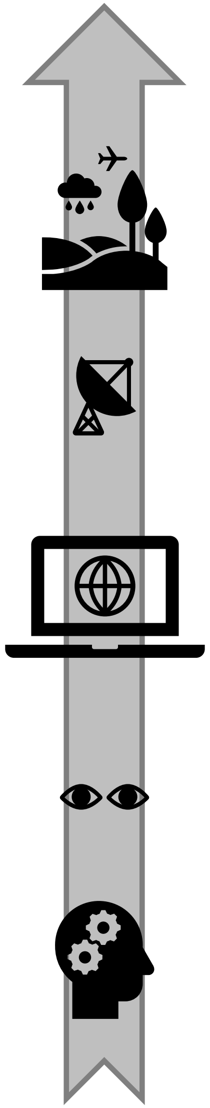


Day 2-4 Agenda



Start (ET)	Event	Speaker
12:00	**Briefing 6**: Breakout session objectives	Facilitator
12:10	**Briefing 7**: Perspective and barriers	David Wing
12:30	**Discussion**: Desirability barriers	Group
1:00	**Discussion**: Desirability chisels	Group
1:30	Break	
1:45	**Discussion**: Viability barriers	Group
2:15	**Discussion**: Viability chisels	Group
1:45	Break	
3:00	**Discussion**: Feasibility barriers	Group
3:30	**Discussion**: Feasibility chisels	Group
4:00	Homework	Facilitator
4:05	End of day	

Breakout Session Objectives

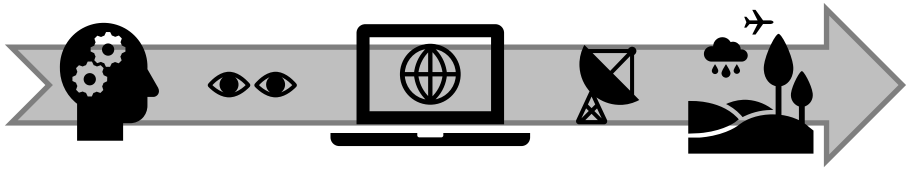
- What we want to get from today:
  - Information gathering through polling
  - "Open mic" discussion within the smaller group
  - Determine how we will break down the barriers to making Digital Flight a reality

Brainstorming Rules

Breakout Session Objectives

- Final Thoughts:
  - Please include your name when submitting responses, this helps with follow-up discussion
  - Recordings of this workshop are for internal analysis only, final reports will not include attributable statements

Questions?



Digital Flight

Breakout Perspectives - Users

User Perspective

Operator

Owner
Dispatcher
Test Pilot
Prospective Operator
Electric Powered
Commercial Pilot
Jet A Powered
Operator
Student Pilot
Public Use
Alternative Fuels
Powered-Lift
100LL Powered
Business Aircraft
Commercial Transports
Fixed-Wing
Conventional Takeoff/Landing
Military Aircraft
Large Cargo Transports
Airships
Midsize Cargo
Rotorcraft
Vertical Takeoff/Landing
General Aviation
Short Field Paved/Unpaved
Balloons
Small UAS
HALE

Purpose

Search and Rescue
Regional trips
Cross-town trips
Transport People
Transport Freight
Cross-country trips
Aerial Inspections
Recreation
Commuting
Atmospheric Science
Deliver Packages
Medical Transfers
Temporary Communications
Freight Distribution
Emergency Support
Flight Training

Objective

Minimum Flight Time
Protect Proprietary Data
Maximum Loiter
On Demand
Predictable Airspace Access
On Time
Real-time Maneuvering
Unconstrained Climb / Descent
Dynamic Optimization
Min Fuel
Low Turbulence
Operational Flexibility
Maximum Range

Scope – What the Digital Flight Vision IS

- A new flight mode
  - Combining some of the best attributes of VFR and IFR
  - Employing technology to overcome some of the limitations of VFR and IFR
- A sustained flight authorization
  - Persistent from take-off to landing (unless operator switches to VFR or IFR)
  - Established by operator “filing a DF flight plan” or some similar declaration
- A capability founded on safety-critical digital connectivity, information, and automation
  - Visual and standard instrument systems and procedures won’t be enough
  - May leverage visual & instrument procedures in certain conditions
- Defined broadly and generally enough to enable diverse applications
  - Can be invoked for various purposes and benefits in different operational domains
  - Can have a variety of performance levels to suit operational need and risks
  - Applicable to all operations (smallest to largest; slowest to fastest; piloted to fully automated)
- Far reaching and sustainable to meet future needs
  - In UAM terms, compatible with UML-5&6

Scope – What the Digital Flight Vision Is NOT

- Not a replacement or displacement of existing flight modes
  - DF complements VFR and IFR as a third alternative with unique attributes
  - DF shares the airspace equitably and cooperatively
- Not a “Concept of Operations” of its own
  - DF is intended to integrate with – and enable – emerging and existing concepts
- Not a complete system design
  - DF is a “concept element” working in concert with other critical elements in the NAS
  - DF is supported by an ecosystem of connectivity, data sources, technologies, and operational rules
- Not a “delegated” procedure
  - DF is the operator’s choice and is not revokable or “cancelled” during flight
- Not a free-for-all
  - DF carries responsibilities for cooperative behavior, information sharing, and safety assurance
  - DF collaborative capabilities may facilitate traffic complexity and flow management
- Not a static capability
  - DF is performance-based, which allows incorporation of continuing technology advances
  - DF is a foundation for long-term innovation

Scope – What the Digital Flight Vision Could Be

- Third complementary set of Flight Rules
  - Design as desired and minimize changes to VFR, IFR
  - But must be generalized to support all types of operations
- Suite of operation-specific Flight Rules (UTM, UAM, ETM, etc.)
  - Each community defines exactly what they need
  - But creates patchwork of rules with complex interplay (or strict segregation)
- Augmented VFR
  - Update “visual” rules to include digital situation awareness and decision-making
  - But must preserve Visual Flight while accommodating significant differences of Digital Flight
- Pre-flight IFR "delegated operation" lasting the whole flight
  - Accommodates Digital Flight as an IFR clearance
  - But complicates rolls and responsibilities of pilots and controllers
- Non-flight-rule operation (like Part 107)
  - Builds on recent precedent
  - But still requires rulemaking to ensure clear responsibilities and performance requirements
- Others?

An Opening Bid for Formalizing Digital Flight

DF Operator Privilege

The DF operator may operate in all airspace classes and flight visibility conditions, while always retaining full responsibility for safety.

Access

The DF operator may operate in all airspace classes in IMC without specific clearance from ATC.

Flexibility

The DF operator may alter the aircraft's flight path without specific clearance from ATC.

Service Provider Use

The DF operator may employ authorized providers of services in the execution of their responsibilities.

DF Operator Responsibility

The DF operator is responsible for protecting the aircraft's flight path from all safety hazards in all flight visibility conditions.

Navigation Responsibility

The DF operator shall manage the aircraft's flight path to ensure safety and unauthorized entry into special activity airspace.

Separation Responsibility

The DF operator shall manage the aircraft's flight path to ensure separation from traffic.

Digital Technology Use

The DF operator shall employ certified digital automation connected to appropriate authorized data sources.

Cooperative Rules and Standards

- Be predictable by flying strategic when able
- Share your intent and keep it current
- Don't create conflicts for others to solve
- Give right-of-way when appropriate
- Coordinate maneuvers when appropriate

Communication
Protocols
Time Horizons
Separation Standards

Right-of-Way Rules
Man. Coordination Rules
Execution Timeliness

Information Management

The DF operator shall receive, store, process, and maintain current all information, as needed to meet their responsibilities.

Flight Path Prediction

The DF operator shall maintain a current digital prediction of the intended flight path and the conformance tolerance.

Cooperative Intent Sharing

The DF operator shall conduct cooperative operations including sharing the aircraft's intended flight path and other information.

Barrier Examples (User Perspective)

Desirability

- "I don't understand / can't quantify the benefits of DF for my operation."
- "I don't want to switch all my operations to DF."

Viability

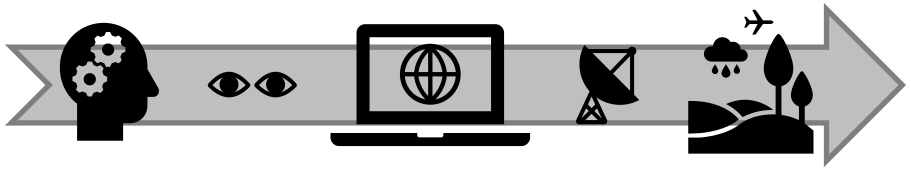
- "If equipping for DF costs more than for IFR, it may not be viable to our business model."
- "Reliance on automation for safety may not be viable long-term as traffic grows."

Feasibility

- "My vehicles are probably too small for DF."
- "I operate in airspace with massively dissimilar aircraft performance, which DF couldn't handle."

Chisel Examples (User Perspective)

- Conceptual analysis that shows potential operational benefits
- Description of attributes that enable any desired balance of DF and non-DF operations
- First-order analysis of equipage and training costs, compared to IFR
- First-order SWAP analysis for small vehicle equipage
- Simulation showing DF interactions between dissimilar-performance vehicles



Digital Flight

Breakout Perspectives - Enablers

Enabler Perspective

Services

Separate IFR Traffic
Wake Vortex Separation
Share PIREPs
Manage Traffic Flows
Issue TMIs
Rerouting Clearance
Expedite Flow
Operator Training
Air Navigation
Traffic Advisories
Manage Departures / Arrivals
Weather Advisories
Publish NOTAMs
Surface Movements
Metering
Flight Plan Clearance
Service-Provider Training
Takeoff/Landing Clearance
First-Come First-Served
Balance Capacity / Demand
Emergency Support
Response Coordination
One-In One-Out
Assign Dep/Arr Procedures

Information

Weather Conditions
NAVAID Status
Runway Conditions
NOTAM Management
Airspace Design
Terminal Delays
Demand / Delay Forecasting
Atmospheric Modeling
Approach Lighting
Special Activity Airspace
Digital / Print Charts
Severe Weather Avoidance Plans
Solar Events
Weather Forecasting
Procedure Design
Temporary Flight Restrictions
GPS RAIM
Navigation Database

Technology

Advanced Algorithms
Control Inceptors
Interval Management
Communication Technologies
Time-of-Arrival Control
Aircraft Manufacturing
Connectivity Infrastructure
Onboard Sensors
Navigation Technologies
Detect and Avoid
Aircraft MRO
Electronic Flight Bags
Precise Navigation
User Interface Technologies
Ground Sensors
Surveillance Technologies
CDTI-Assisted Separation
Connected Avionics
Flight / ATC Simulators
EFB Applications
Data Exchange
Command and Control Links
Satellite Sensors

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Barrier Examples (Enabler Perspective)

Desirability

- “DF aircraft operating in controlled airspace could disrupt IFR traffic flows.”
- “DF operations would be too unpredictable.”

Viability

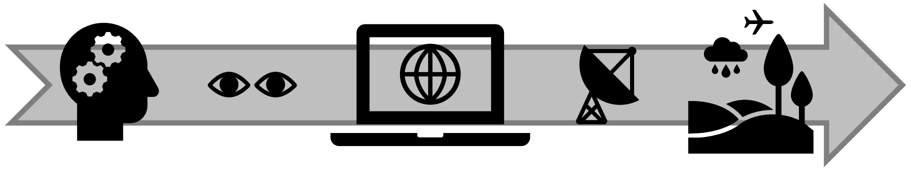
- “Federation of service provision would be too complex as traffic grows.”
- “Automation has not been certified to the level required for DF.”

Feasibility

- “There may be insufficient spectrum to handle DF communications at scale.”
- “Integrating DF & non-DF operations in arrival flows is unmanageable.”

Chisel Examples (Enabler Perspective)

- Simulation of DF aircraft and IFR traffic flows
- Description of attributes of DF that yield predictability
- Analysis that produces a viable certification path for an example automation function
- First-order spectrum analysis and identification of candidate right-sizing approaches



Digital Flight

Breakout Perspectives - Protectors

Protector Perspective

Regulator

Rule Making
Certification
Regs & Policy
Type Certificates
Supplemental Type Certificates
Technical Standard Orders
Operation Approval
Operational Specifications
Advisory Circulars
Airworthiness Directives
Designated Engineering Representatives
Operations Inspectors

Safety Specialties

Safety Management Systems Developer
Safety Analyst
Accident Investigator
Safety Manager
Ramp Inspector
Safety Auditor
Designated Examiner
Medical Examiner
Flight Deck Design
ATC Station Design
User Interface Design
Standard Operating Procedures
Checklists
Duty Scheduling
CRM Procedures
Standard Phraseology

Research

Human Factors Specialists
Human Performance
Emerging Safety Constructs
In-Time Safety Management
Human-Automation Teaming
Trust in Automation
Function Allocation
Standards Development
Means of Compliance
Fault-Tolerant Design
Run-time Assurance
Formal Methods
Deconfliction Algorithms
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Envelope Protection
Concept Development
BVLOS Research
Distributed vs. Centralized
Simplified Vehicle Operations
Operational Autonomy
Reduced Crew Operations
Auto-land Roadmap

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Barrier Examples (User Perspective)

Desirability

- “Safety in distributed systems like DF is harder to manage than in centralized systems.”
- “DF would degrade piloting skills through reliance on automation.”

Viability

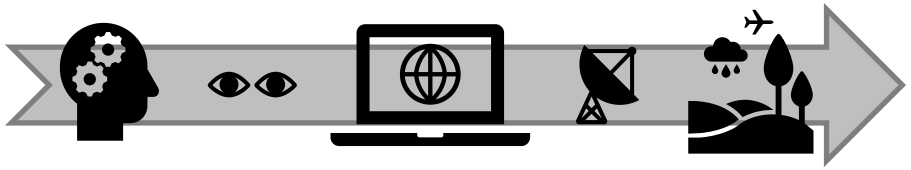
- “Cybersecurity could be a greater threat under DF operations.”
- “The crawl-walk-run path for DF is unclear.”

Feasibility

- “Certifying automation to assume traditionally human roles may not be possible.”
- “Rules and standards will be difficult to define for highly differentiated aircraft performance.”

Chisel Examples (User Perspective)

- Literature review of separation assurance in distributed and centralized systems
- Analysis of piloting skills required in mature-state DF
- First-order cybersecurity analysis
- Simulation of DF operations with aircraft with highly-differentiated performance



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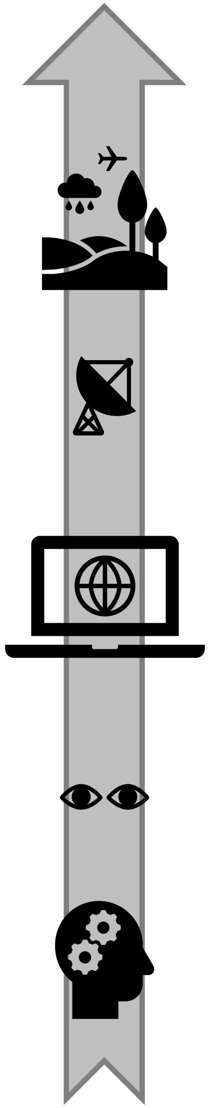
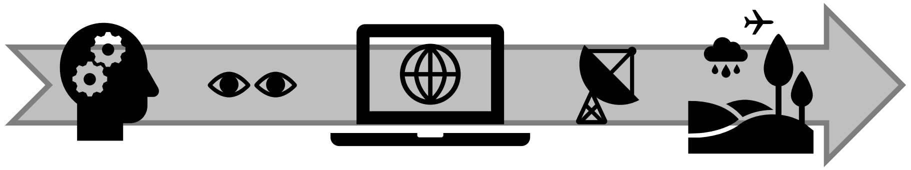
Final Day Agenda



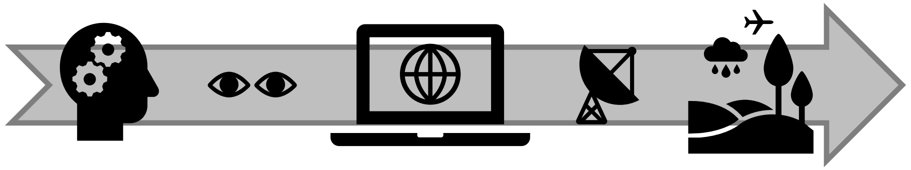
Start (ET)	Event	Speaker
12:00	**Briefing 8**: Breakout results summary	Facilitator
12:20	**Discussion** – stakeholders to engage	Group
12:50	**Guest speaker** on “The Vision”	To be announced
1:00	**Discussion** – new standards needed	Group
1:30	**Guest speaker** on “The Application”	To be announced
1:40	**Discussion** – new services needed	Group
2:10	**Guest speaker** on “The Implications”	To be announced
2:20	BREAK	
2:40	**Discussion** – steps forward	Group
3:10	**Guest speaker** on “The International Relevance”	To be announced
3:20	**Discussion** – Insights, recalibration	Group
4:00	**Briefing 9**: Wrap-up / how to stay involved	Keith Wichman
4:10	Happy Hour (optional “stay after” discussion)	David / Ian
4:30	End of workshop	

Breakout Session Summary

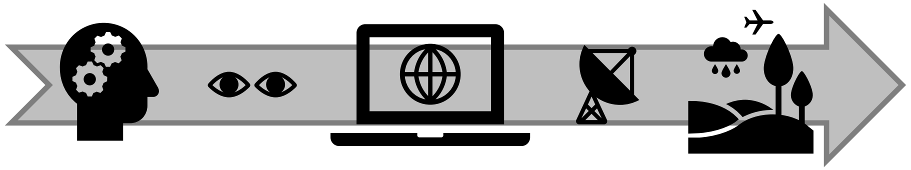
- Summary of breakout session / CAS DVF Analysis
- Content to be developed Sonalysts after breakouts / briefed by Facilitator
  - Expected content areas
    - Polling results
    - Major themes
    - Noted contrasts between "perspectives"



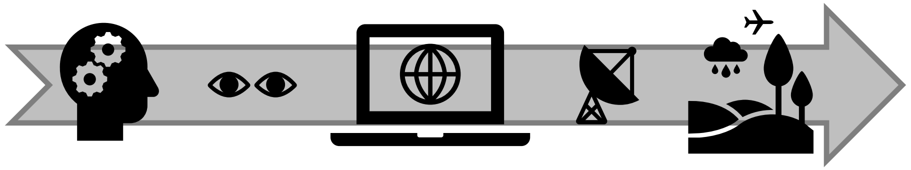
Guest Speaker
Bill Cotton



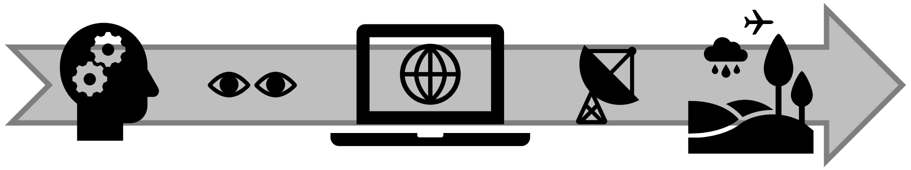
Guest Speaker
Anna Dietrich



Guest Speaker
Randy Willis



Guest Speaker John Walker



Digital Flight Workshop Wrap-Up

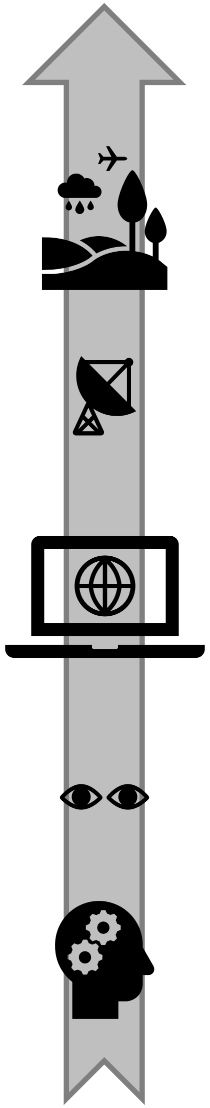
DF Workshop Plan and Schedule

- ✓ Day 1: Introduction
  - New capability defined
  - Previous initiatives of similar scope
  - Current rules analysis
  - Scope of Digital Flight
- ✓ Days 2-4: Perspectives
  - 3 days, 3 perspectives: Users, Enablers, Protectors
  - CAS analysis: desirability, viability, feasibility
  - Barriers, chisels
- ✓ Day 5: Plenary
  - Roll-up
  - Other perspectives
  - Recalibration
  - Next steps

Digital Flight Workshop Wrap-Up

- Closing remarks by CAS Project Manager, Keith Wichman
- Content to be developed CAS following the breakouts
  - Some thoughts to possibly include
    - Perspective on achievement of workshop objectives
    - Next steps from CAS Project perspective
    - How to stay involved in DF (with NASA and outside of NASA)
    - Thanks to all the facilitators and organizers
    - Thanks to all the participants

Final Day Agenda



Start (ET)	Event	Speaker
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