On-Demand Mobility and Emerging Aviation Technologies Roadmapping Workshop: Overview

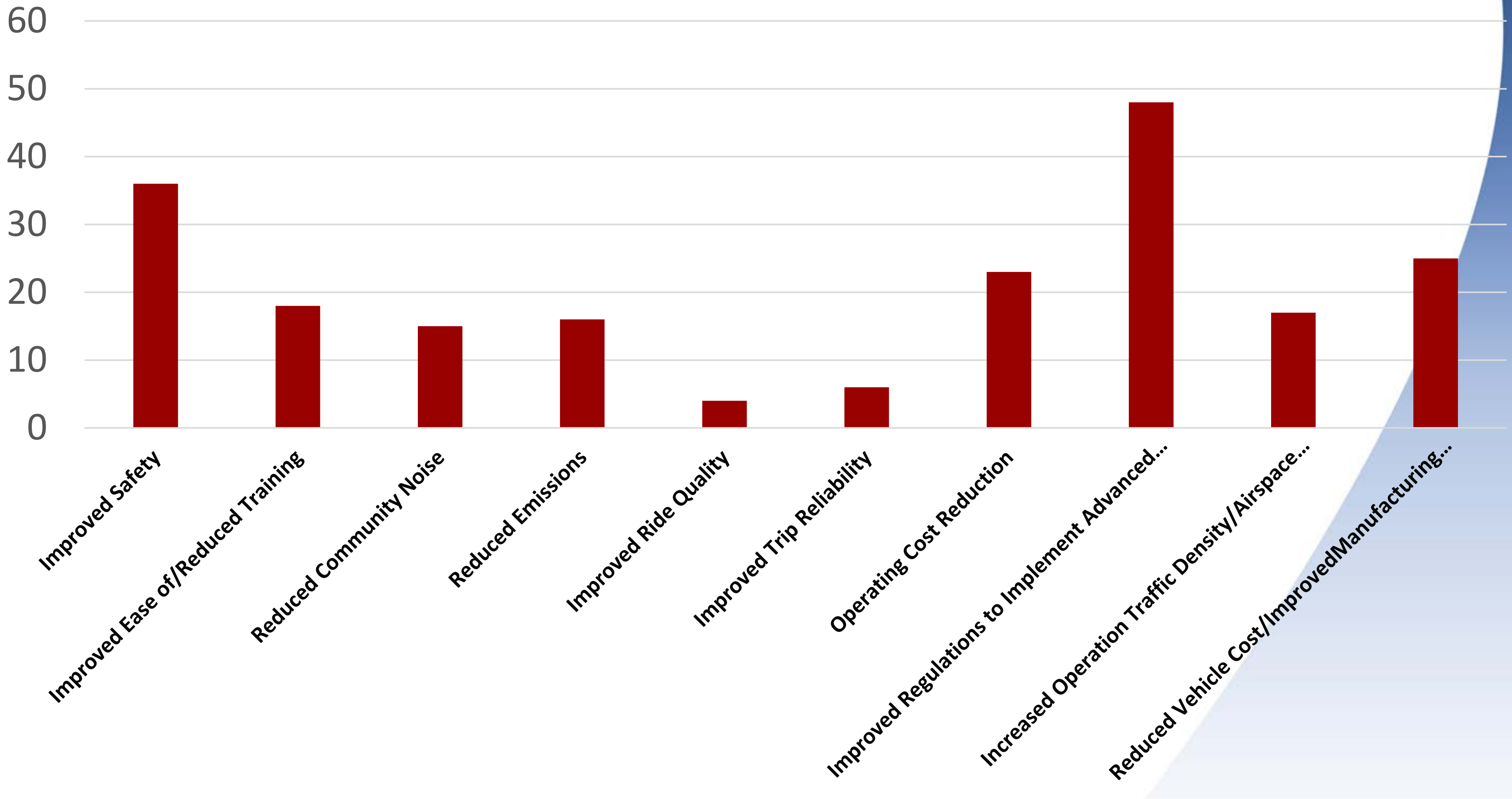
Ken Goodrich, Senior Research Engineer, NASA Langley

October 21, 2015

Workshop Outcomes—More than Roadmap

- **Community**
- **Vision for ODM and On-Demand Aviation (ODA)**
- **Preliminary technology roadmap**
  - Critical enabling capabilities
  - Technology gaps & barriers
  - High-priority, technologies and supporting precompetitive tools, guidelines, standards and certification methods
- **Working groups to continue roadmap development beyond workshop**
- **Partnership and research opportunities**

Areas of Interest from Registration Survey



Workshop Overview

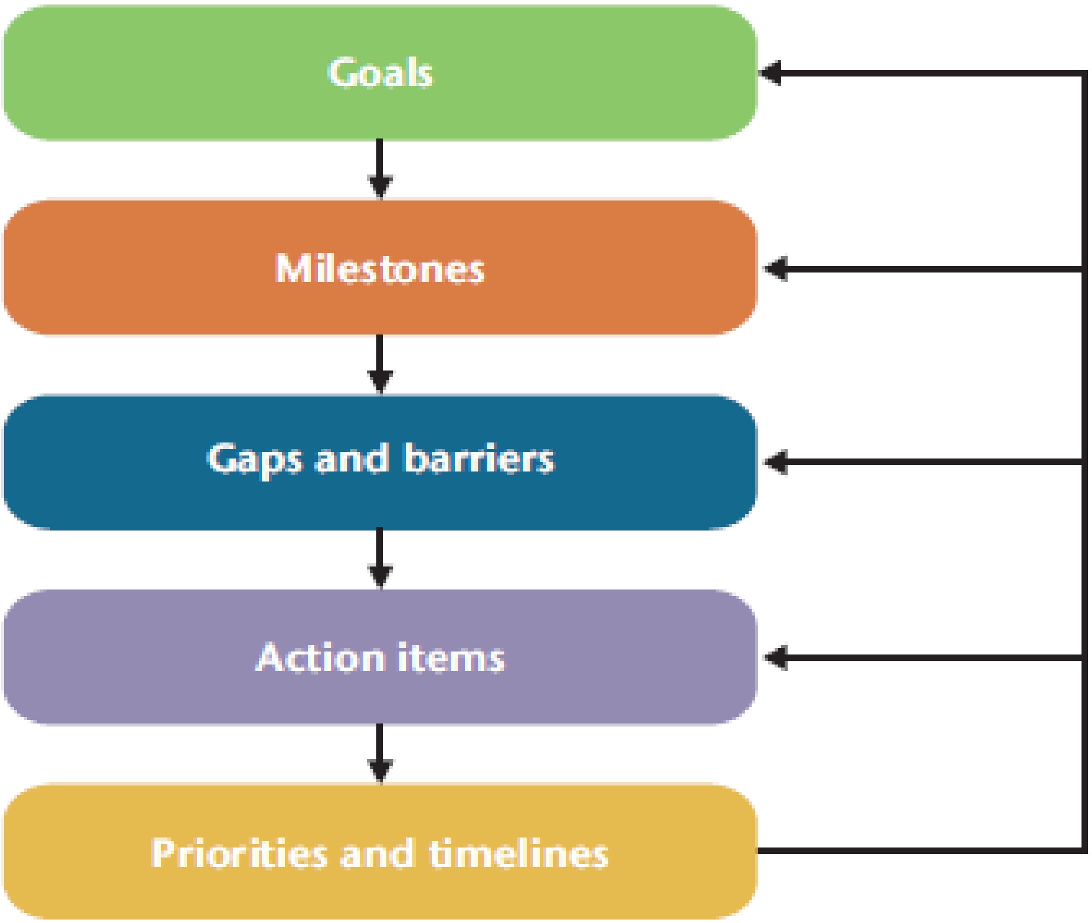
October 21: Developing common vision and understanding

- Workshop overview and introductions
- NASA’s emerging ODM vision and technology interests
- FAA thrusts and priorities
- Industry and academia perspectives
- Full-group discussion: Top priorities and supporting-priorities

October 22: Roadmap and Partnership Building

- Roadmapping overview & preliminary examples
- Roadmapping breakout sessions
- Breakout session reports
- Partnerships discussion
- Post-workshop working groups
- Wrap-up, adjourn

Roadmap Elements



Roadmap Elements, cont.

Goals: a clear and concise set of targets that, if achieved, will result in the desired outcome; quantified goals (e.g. "improve energy efficiency in commercial buildings by 25% in ten years") provide the most specific guidance.

Milestones: the interim performance targets for achieving the goals, pegged to specific dates (e.g. "improve the energy efficiency of commercial buildings by 2% per year during the next five years without slowing economic growth").

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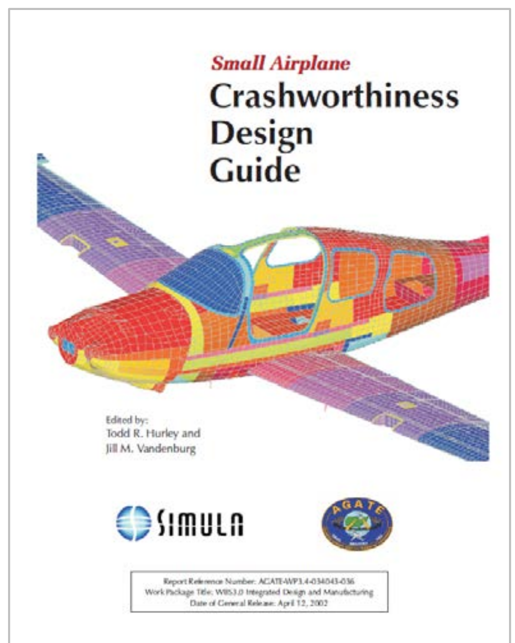
Pre-Competitive Research and Products

- **The focus of any R&D collaboration in the U.S. must by law be on precompetitive deliverables**

- **Public-good primary justification for public investment**
  - Public benefit without private preference desired
  - Temporary, head-start for certain types of contracts & agreements(e.g. 5 year nondisclosure period for SBIRs)

- **For aviation, typically**
  - Industry design tools and guidelines
  - System and operational standards (e.g. RTCA MASPS and MOPS)
  - Certification Methods

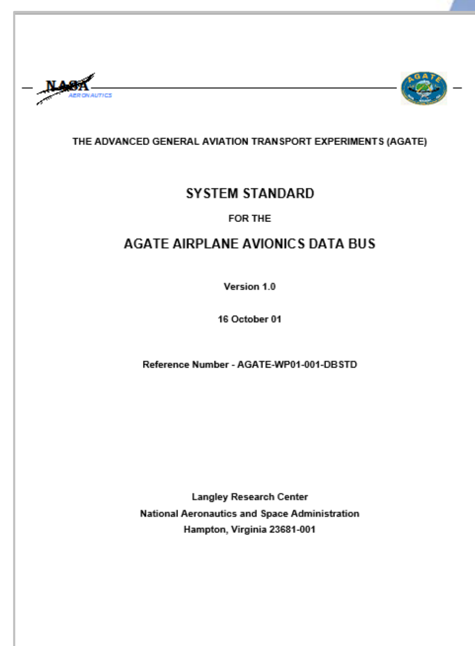

Small Airplane
Crashworthiness Design Guide

Edited by:
Todd R. Hurley and
Jill M. Vandenburg

SIMULA

AGATE

Report Reference Number: AGATE-WP3.4-034043-036
Work Package Title: WBS3.0 Integrated Design and Manufacturing
Date of General Release: April 12, 2002


NASA AERONAUTICS

AGATE

THE ADVANCED GENERAL AVIATION TRANSPORT EXPERIMENTS (AGATE)

SYSTEM STANDARD
FOR THE
AGATE AIRPLANE AVIONICS DATA BUS

Version 1.0

16 October 01

Reference Number - AGATE-WP01-001-DBSTD

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia 23681-001

Questions?

Introductions

- NASA
- FAA and other Government
- Nonprofit and Edu
- Industry

Workshop Participants, NASA

NASA	Organization	Title
Rohn, Douglas	Headquarters	Program Director, Transformative Aeronautics Concepts
Ginn, Tony	Armstrong	Technical Manager
Jankovsky, Amy	Glenn	Deputy Project Manager, UAS NAS Integration Project
Jansen, Ralph	Glenn	AST, Electrical Power Systems
Finelli, George	Langley	Head of Aeronautics Research Directorate
Ferebee, Michelle	Langley	Strategy and New Business Manager
Moore, Mark	Langley	Senior Advisor for On-Demand Mobility
Goodrich, Ken	Langley	Senior Advisor for On-Demand Mobility
Bauer, Steven	Langley	Research Directorate, Fluid Mechanics
Fredericks, William	Langley	AST, Aeronautics Systems Analysis
Holland, Scott	Langley	Deputy Director, Systems Analysis & Concepts Directorate
Mukhopadhyay, Vivek	Langley	Senior Aerospace Engineer, Structural Dynamics
Parikh, Paresh	Langley	Associate Director for Projects
Patterson, Michael	Langley	AST, Aeronautics Systems Analysis
Rhew, Ray	Langley	Head, Aeronautics Systems Engineering Branch
Rippy, Lisa	Langley	Head, Crew Systems and Aviation Operations Branch

Workshop Participants, FAA & other Government

FAA	Organization	Title
Johnson, Mel	Small Aircraft Directorate	Acting Directorate Manager
Fernandez, Jorge	Engine and Propeller Directorate	Aerospace Engineer
Foster, Lowell	Small Aircraft Directorate	Flight Test Engineer
Greene, Kevin	Transport Airplane Directorate	Flight Test Pilot
McGuire, Robert	Aviation Research Division (Tech Center)	Aerospace Engineer
Ryan, Wes	Small Aircraft Directorate	Manager, ACE-114
Sizoo, David	Small Aircraft Directorate	Exp Flight Test Pilot and HF Specialist
Sparacino, Peter	Aviation Research Division (Tech Center)	FAA Program Manger for the Center of Excellence for Aviation
VanHoudt, John	Small Aircraft Directorate	Aerospace Engineer
Witzig, William	Engine and Propeller Directorate	Flight Test Pilot

DoD		
Schultz, Warren	Naval Research Laboratory	Associate Superintendent, Chemistry Division

Workshop Participants, Non-Profit and Edu

Nonprofit and Edu	Organization	Title
Landsberg, Bruce	AOPA	Senior Safety Advisor
Aldag, Tom	National Institute of Aviation Research	Director, R&D
Stanley, Doug	National Institute of Aerospace	President
Crossley, William	Purdue University/FAA Center of Excellence for General Aviation	Professor of Aeronautics and Astronautics/PEGASAS Director
Hook, Loyd	University of Tulsa	Professor
Zheng, S. Charlie	University of Kansas	Professor

Workshop Participants, Industry

Name	Company
Alejo, Dominique	SAFRAN
Anemaat, Willem	Design, Analysis and Research Corporation
Anghel, Christian	Honeywell
Armstrong, Mike	Rolls-Royce North American Technologies, Inc.
Bar-Yohay, Omer	Eviation LLC
Berry, Scott	Joby Aviation
Bevirt, JoeBen	Joby Aviation
Burkhardt, Marc	Avionics Technologies, Inc.
Chu, Joseph	Rolls-Royce North American Technologies, Inc.
Crosland, Jermaine	KMT
Devine, Thomas	Thomas International, Inc.
Dietrich, Carl	Terrafugia

Name	Company
Duerksen, Noel	Garmin
Engler, Jeff	Current Airplanes
Foster, Trevor	Empirical Systems Aerospace, Inc.
Gundlach, John	Gundlach Aerospace LLC
Gunnarson, Tom	Zee Aero
Hoffler, Keith	Adaptive Aerospace Group
Holmes, Bruce	Holmes Consulting LLC
Hymer, Jeff	HI-Lite Aircraft
Jackson, Bruce	Adaptive Aero
Jackson, Joseph	Scientific Systems Company, Inc.
Knapp, Matt	Tzunum
Kraus, Emmett	Kraus Aero
Kwon, Omun	Skurka Aerospace Inc.
Latham, Geoffrey	Bell Helicopter

Workshop Participants, Industry

Name	Company
Liu, Wanbo	Design, Analysis and Research Corporation
Masson, Paul	StarNet, LLC
McCloskey, Dave	Current Airplanes
McGinnis, John	Synergy Aircraft
Mochida, Kazuhiko	TEMA
Neuman, Tom	Toyota (TTC)
Nuss, Marv	Nuss Sustainment Solutions
Ouellette, Richard	Boeing
Prokhorov, Danil	TTC-TRINA
Rathbun, Dave	Vision SF50
Richardet, Brian	Textron Aviation
Rodeman, Boyd	Textron Aviation
Santucci, Chris	Toyota Motor North America, Inc.

Name	Company
Sarh, Branko	Boeing
Schlitter, Randy	RANS Designs Inc.
Sciarra, Paul	
Shavit, David	IAI
Skriba, Bud	Giajoule Jug Consulting
Smith-Velazquez, Laura	Rockwell Collins
Thibodeau, Phillip	Avionic Instruments LLC
Turnbull, Andy	SAFRAN
Tzidon, Dekel	Phinergy LTD
Willford, Neal	Textron Aviation (Cessna)
Ximenes, Samuel	XArc Exploration Architecture Corporation
Yadgar, Avi	Phinergy LTD
Yarbrough, Jon	Yarbrough Capital

Industry and Academia Perspectives

12:30 PM	Joby Aviation
12:45 PM	Phinergy LTD
1:00 PM	Tzunum
1:15 PM	Eviation LLC
1:30 PM	Avionics Technologies, Inc.
1:45 PM	Honeywell
2:00 PM	Emmett Kraus
2:15 PM	Naval Research Laboratory
2:30 PM	AOPA Senior Safety Advisor
2:45 PM	IAI
3:00 PM	Adaptive Aerospace Group
3:15 PM	University of Kansas
3:30 PM	Boeing

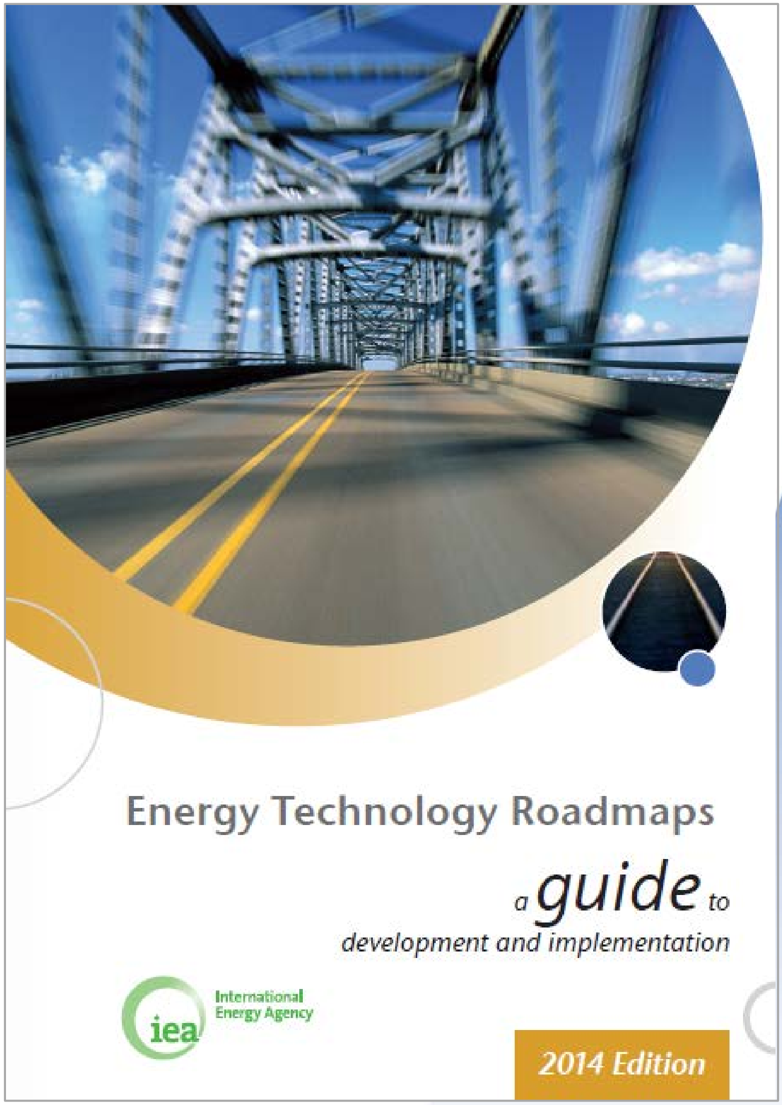
Roadmapping Breakout Session Overview

Ken Goodrich

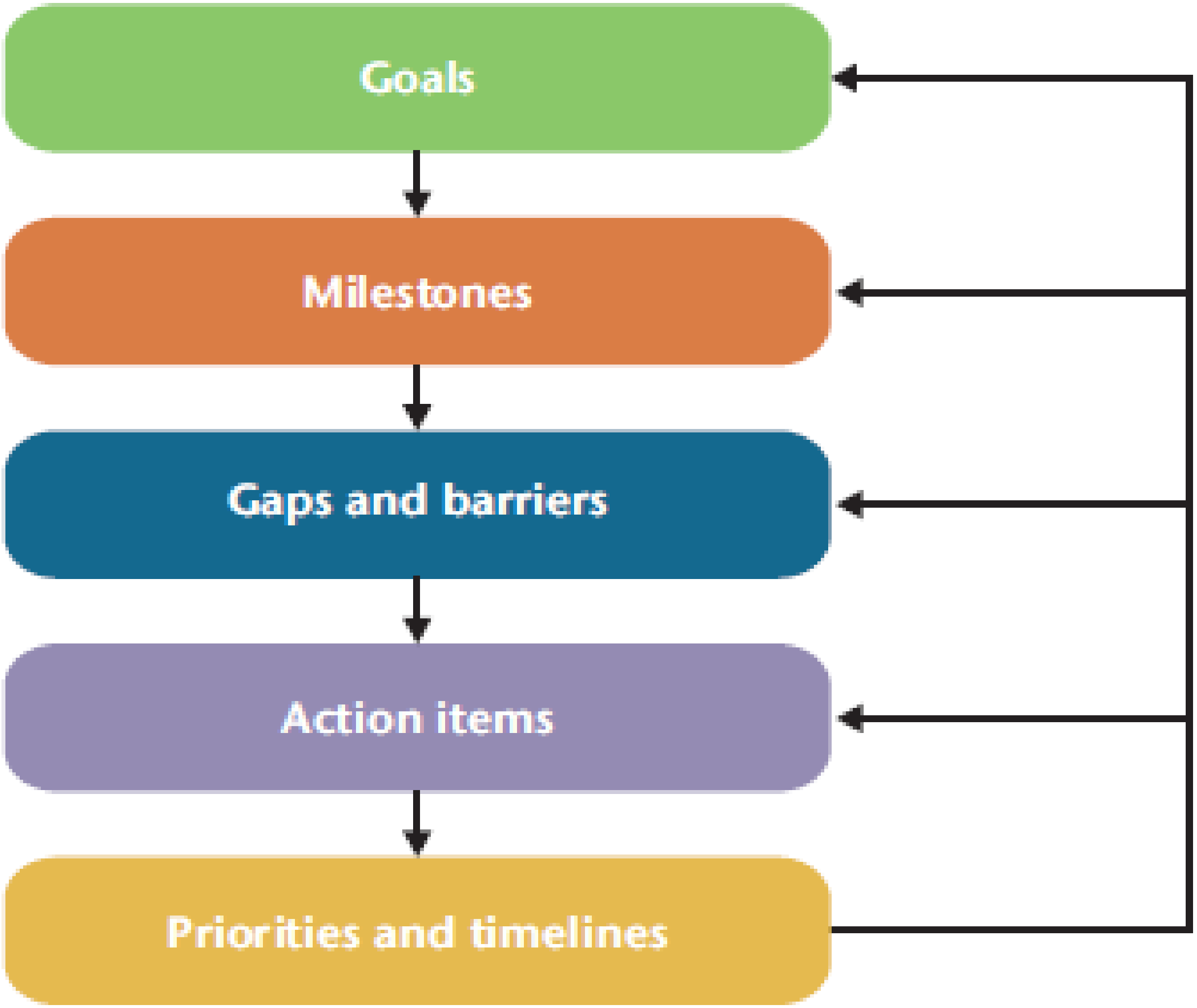
October 22, 2015

Definition

Roadmap: a specialized type of strategic plan that outlines activities an organization can undertake over specified time frames to achieve stated goals and outcomes.



Roadmap Elements



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Goals for Today's Breakout Sessions

- Build on priorities expressed during yesterday afternoon's group discussion
- Breakouts for EP, SVO, and Other
- 3 x 30 minute sessions for participation in multiple topics
  - Encouraged to rotate, but may repeat
- Process
  - Facilitators briefly surmise previous sessions
  - Clarify goals, milestones, gaps & barriers as needed (~5 minutes)
  - Primary focus is on identifying possible technical approaches and supporting actions (e.g. studies) and pre-competitive products (~15 minutes)
  - Briefly consider desired (but realistic) timeframe for key products (~5 minutes)
  - Today's focus on capturing action space of participants; refinement comes later
  - Express dissent but allow majority to continue

Questions / Comments ?

Simplified Vehicle Operations Example Roadmap Decomposition

Ken Goodrich

October 22, 2015

Top-Level ODM Barriers & SVO

- **<u>Current General Aviation (GA) Aircraft compared to Commercial Airliners</u>**

- **Poor Aerodynamic and Propulsive Efficiencies**
  - Aerodynamic efficiency measured as Lift/Drag ratio is 9-11 compared to 17-20.
  - (Thermal) x (propulsive efficiency) of 20-24% compared to 36-40%.
- **Poor Emissions**
  - High Hydrocarbon, Green House Gas emissions, particulates and lead pollution.
- **Poor Community Noise**
  - Similar levels and certification compliance with few improvements for the past 50 years.
- **Poor Comparative Safety**
  - **Accident rate 56x worse than airlines, 15x worse than autos per 100 million vehicle miles traveled**.
- **Poor Ride Quality**
  - Low wing loading leads to bumpy ride along with gust sensitivity. (Note, technology needed for SVO also applicable to active gust alleviation)
- **Poor Dispatch Reliability Rate**
  - Maintenance and weather sensitivity result in <70% rate for trip completion.
- **Substantially Higher Operating Costs**
  - Compared to all other transportation options (car, airline, train).
- **Onerous Training Requirements**
  - Currently only 0.18% of the U.S. population is capable of flying GA aircraft compared to 69% who have a driver's license.

SVO Roadmap: Goals

- **Flight systems, interfaces, and operations that make ODM aviation as accessible and practical as driving + safer**
- **Simplified control of conventional and novel aircraft configurations**
- **Approach aligned with developing and operationally proving technologies beneficial to transport and other aviation operations**

SVO System Elements

- **Pilot**
- **Aircraft and systems**
- **Remote support (e.g. dispatch, ground-pilot)**
- **Airspace System & Operations**
  - Relatively inflexible in the near-term
  - Must design for the present and possible futures
  - Some near-term operational simplification possible by limiting navigation and operation options (…with some negatives)

Possible SVO Work Breakdown Structure

- 1) System concepts, integration, and evaluation
- 2) Pilot certification and training
- 3) Pilot-vehicle interface
- 4) Flight and trajectory control
- 5) Autonomous vehicle awareness, decision support, and hazard avoidance
- 6) Integrated vehicle health management
- 7) Safety-critical systems
- 8) Remote flight and decision support
- 9) Airspace Operations and Integration

Milestones: 3 SVO Epochs, 10 years?

- **SVO-1,** (2016-2026): **Foundational Precedents & Capabilities**
- **SVO-2:** (2021-2036): **SPC, Simplified Pilot Certificate**
- **SVO-3,** (2031-2051): **Autonomous Operations,**

Milestones: 3 Epochs of SVO

SVO-1: Foundational Precedent and Supporting Capabilities

- Demonstrate transition of key skill/capability from pilot to aircraft
  - E.g., Simplified path control
- Moderate workload peaks and specialized skills
- Mitigate pilot as single-point of failure (…automation back-stops pilot)
- Other considerations:
  - Expect only incremental airworthiness certification accommodation, but lays foundation for future
  - Current FAA training required (e.g. ab initio-to IFR in minimum of 70 hours with combined private-instrument curriculum), but new pilots capable of more confident, near-all weather ops.
  - Benefits/grows thin-haul, air taxi, current and early adopter private-pilot markets
  - Operational experience for SVO-2, Part 121, and UAS applications
  - Operate within current and planned NextGen Airspace

Milestones: 3 Epochs of SVO

SVO-2 (2021 – 2036): SPC, Simplified Pilot Certificate

- Simplified training & licensing based on research and operational experience from SVO-1
- Regulatory changes to knowledge, training, and experience requirements
  - Goal ab initio to near-all weather pilot in <40 hours (similar to driver training)
  - Reduced training, experience requirements for Thin-Haul pilots
- New flight system, interfaces, and operation standards that allow updates to training and operational regulations in Part 61, 91, and 135 taking full advantage of technology
  - E.g. possible expansions to Part 135 operations
- Initial airspace accommodations for simpler & higher-volume operations
  - Automated management of non-towered airports
  - More frequent use of data comm.

Milestones: 3 Epochs of SVO

SVO-3 (2031 - 2051): Autonomous Operations

- Combination of aircraft and any off-board board support shoulder command responsibility; nominally accommodates user direction, but may modify or inhibit if deemed unsafe or disruptive

- Vehicle, automation, and airspace fully integrated
  - >>10x current operations
  - Runway independent operations very common
  - No need for voice communication

Example SVO-1, Gaps and Barriers

- Knowledge
- Standards
- Regulatory
- Economic
- Public acceptance

Example SVO-1, Gaps and Barriers

➢Knowledge

- Optimal roles, responsibilities, interfaces for simplified path control, systems, and mission management
- Autonomous situation awareness, decision support, hazard protection with CRM-like interaction
  - E.g. context aware including own limits,
- Ultra-high integrity, available systems with graceful degradation
- Alternate systems for safe recovery (e.g. ballistic chute)
- Aids to simplify interactions with current and planned ATM system

➢Standards

➢Regulatory

➢Economic

➢Public acceptance

Example SVO-1, Gaps and Barriers

- **Knowledge**
- **Standards**
  - Design & flying qualities standards for simplified path control, normal and degraded modes
  - SVO equivalent of Basic-T & GAMA Publication #10
  - Standard architecture & AC23.1309 analysis
  - Minimum operatizing performance standards avionics
- **Regulatory**
- **Economic**
- **Public acceptance**

Example SVO-1, Gaps and Barriers

- **Knowledge**
- **Standards**
- **Regulatory**
  - Certification standards for core capabilities
  - Modified training and operational regs.
- **Economic**
- **Public acceptance**

Example SVO-1, Gaps and Barriers

- **Knowledge**
- **Standards**
- **Regulatory**
- **Economic**
  - Reusable, open architecture/design for flight-critical systems, reduced non-recurring development costs
- **Public acceptance**

Example SVO-1, Gaps and Barriers

- **Knowledge**
- **Standards**
- **Regulatory**
- **Economic**
- **Public acceptance**
  - Traveling demonstration for travel and transportation trade-shows

Summary

- **Examples only—not constraints**
- **Time today is limited**
  - Big picture, avoid weeds
  - Will flesh-out post workshop

- **Questions?**