FAA REDAC Subcommittee on Environment & Energy

Federal Aviation Administration

Fuel Efficiency Metric Development Efforts

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Team

The fuel efficiency metric research project started during September 2013.

Research team members:

- Booz Allen Hamilton
- DOT Volpe Center

Motivation & Objective

- **Motivation**
  - There is an ICAO aspirational goal to improve NAS-wide fuel efficiency by 2% per year, which is based on the goal defined by International Civil Aviation Organization (ICAO).
  - However, the metrics used by FAA and ICAO are different given the FAA has not had the necessary data inputs to accurately compute ICAO metric

- **Objective**
  - The objective of this project is to develop and assess robust system-wide fuel efficiency metrics using publically available data in order to reevaluate and potentially harmonize existing metrics
  - This new metric will allow for greater consistency between FAA and ICAO fuel efficiency definitions, as well as an improvement in the understanding of system-wide benefits of NextGen in terms of tracking of year-on-year changes.

Background

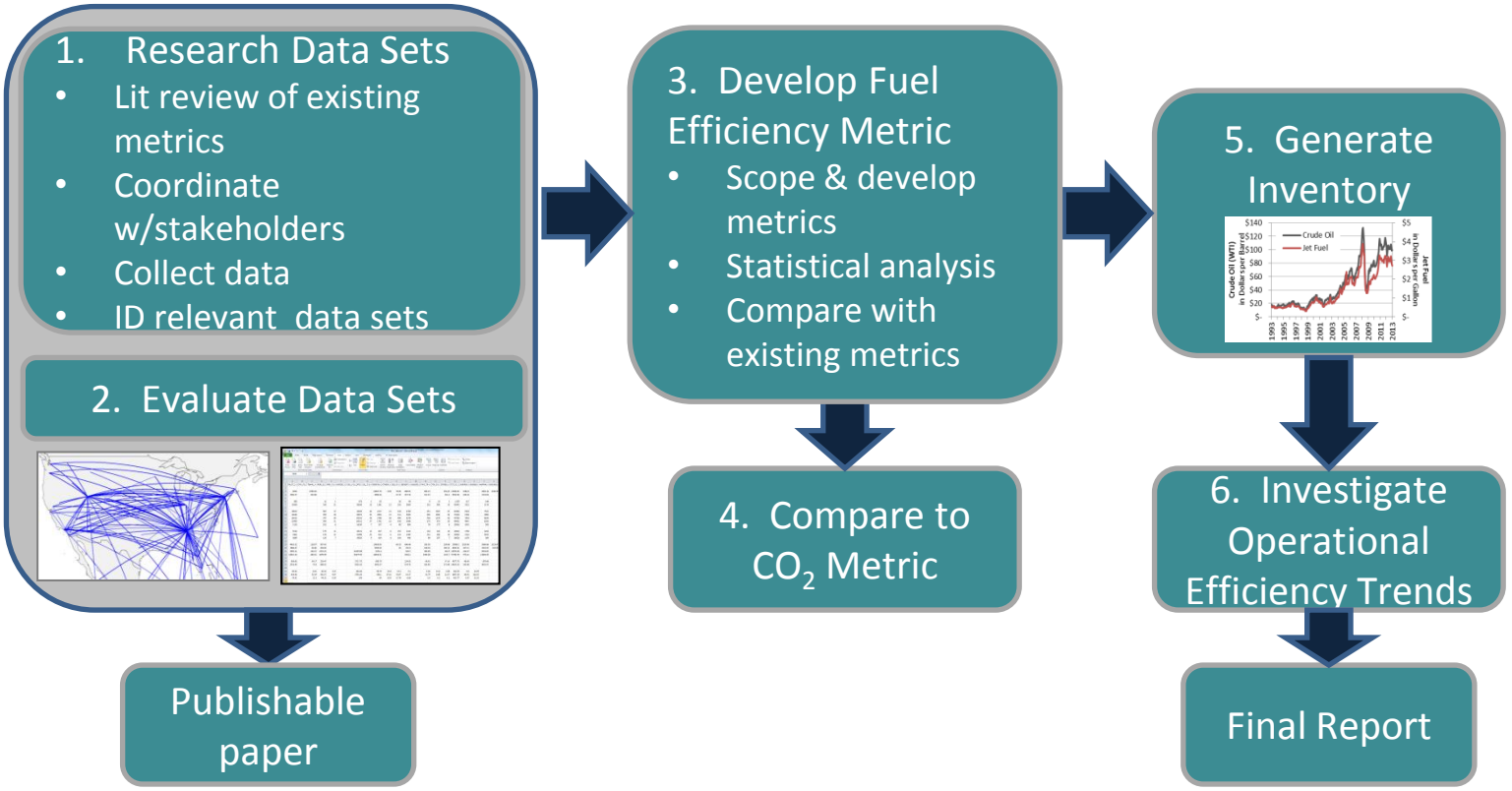
- FAA's current aviation fuel efficiency metric is used to track the cumulative reduction in fuel burn flown per unit of distance for all US commercial operations:

$$Fuel\ Efficiency = \frac{Fuel\ Burned\ (Tg)}{Track\ Distance\ (billions\ of\ km)}$$

- This metric is not expected to meet a 2% per year improvement, as it does not account for payload carried over flown distance
- For this metric the use of track distance instead of great circle distance (GCD) in the denominator potentially masks fleet improvements from fuel efficient technology and new operational procedures
- A combination of parameters for international and domestic flights to be investigated for the definition of a new fuel efficiency metric

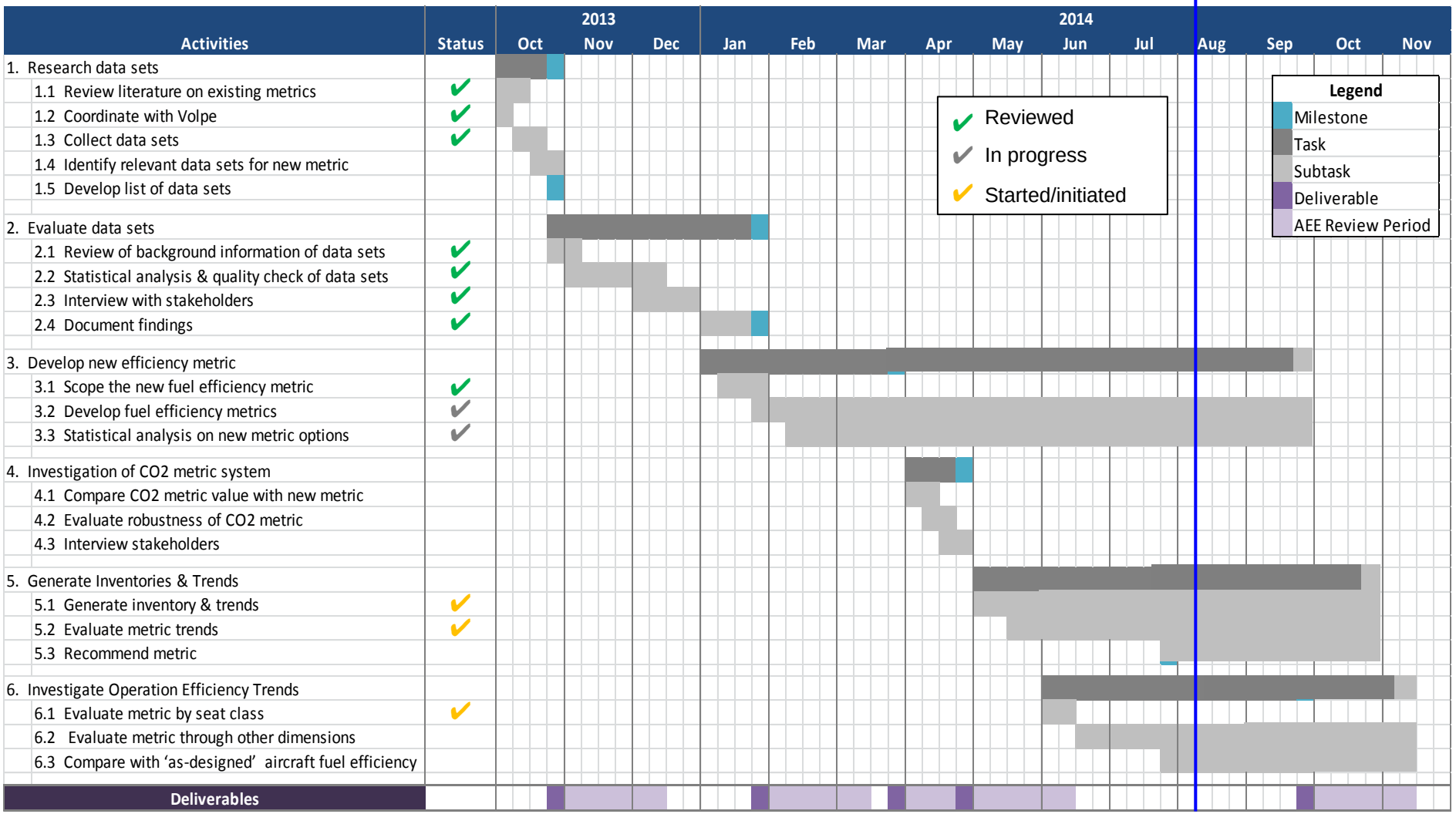
Overview of Approach

- Research and evaluate datasets and existing metrics, develop the new fuel efficiency metric and compare to the CO_2 metric, generate and analyze trends.



Schedule

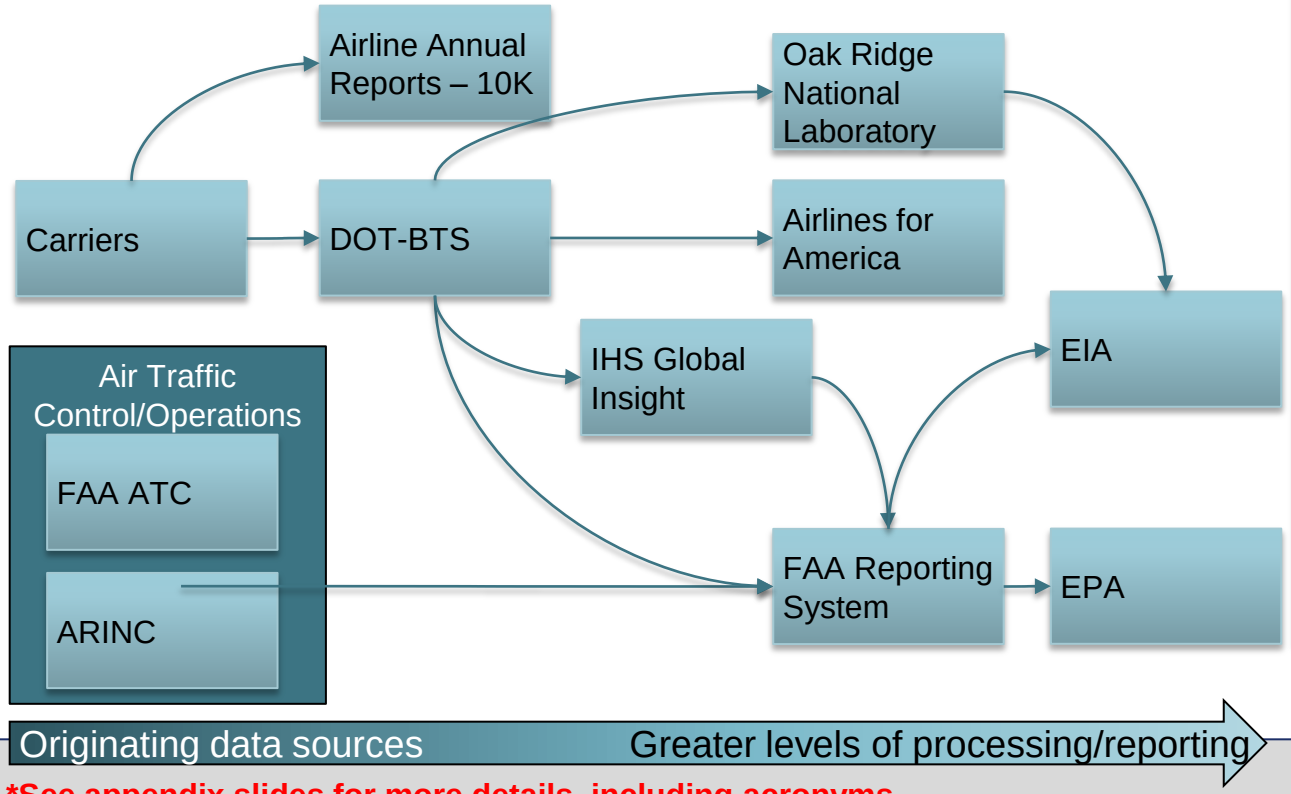
8/06/2014



Data Sources & Existing FE Metrics

- Developed a database of relevant data sources and fuel efficiency metrics
- Data sources covered a wide range of metric elements of interest
- Existing FE metrics were reviewed and evaluated for benefits and limitations

Illustration of Data Source Flow



Data Source and FE Metrics Statistics

- 24 "database" data sources identified
  - 15 contain fuel burn data
  - 7 contain cargo and/or pax data
- 3 "analysis tool" data sources identified (BADA, AEDT, Piano-5)
- 14 fuel efficiency metrics identified from 9 sources
  - 4 contain payload
  - 10 contain fuel mass
  - 5 contain fuel energy

***See appendix slides for more details, including acronyms.**

Major Milestones to-date

- **Completed tasks 1-2 (research and evaluation of datasets) and several iterations of task 3 (metric development)**
- **Coordinated with BTS Office of Airline Information and Volpe in assessment of relevant data sources**
- **Developed and applied evaluation criteria on relevant data sources**
  - Based on this assessment, the BTS T2 and FAA-EPA databases appear to align the most with requirements for metric
- **Completed a draft journal paper on extensive review of data sources & existing metrics**
- **Down-selected potential FE metrics, through the development and application evaluation criteria for 3 main categories of metrics** (Fuel Burn / Distance, Fuel Burn / Payload, Fuel Burn / RTM)
  - Based on preliminary analysis, FE metrics based on BTS data sources appear to show greatest consistency in trends
  - Metrics based on fuel burn / RTM appear to best meet objectives and criteria
- **Developed methodology to calculate candidate metrics for annual inventories**

Next Steps

- **Finalize paper on quality assessment of data sources, and consider options for publication**
- **Compute top metric candidates for key years and investigate annual inventory trends (Tasks 5&6)**
  - Inform decision on most promising metric
- **Conduct comparison between selected metric and CO_2 metric (Task 4)**
  - Determine any potential linkages between the final FE & CO_2 metrics
- **Develop final report**
  - Capture the approach, findings, provide recommendations and any suggest next steps (Task 7)

Questions?

Appendix

Acronym List

- FAA ATC – Federal Aviation Administration Air Traffic Control
- ARINC - Aeronautical Radio, Incorporated
- DOT BTS – Department of Transportation Bureau of Transportation Statistics
- AEDT – Aviation Environmental Design Tool
- BADA - Base of Aircraft Data (EUROCONTROL)
- EIA – Energy Information Administration
- EPA – Environmental Protection Agency
- ICAO – International Civil Aviation Organization
- RTM - Revenue pound miles, weight carried multiplied distance carried

Fuel Efficiency Metrics Literature Review

The following matrix provides a high level overview of the literature sources of fuel efficiency metrics that have been evaluated. Detailed information of this literature review will be available in the project's paper on extensive review of data sources & existing metrics.

					Elements of Metric													
			Level of Disaggregation		Fuel				Productivity									
Metric	Forumulation	Organization/ Source	By A/C	NAS/ System-wide	Fuel Mass (kg)		Fuel Energy (BTU)		Cargo weight	No. of Pax	Depart-ures	GCD	Actual distance flown	Flight time	RPM	ASM	Cargo RTM	Load Factor
					Block	*Simplified Mission*	*Block*	*Simplified Mission*	lb	n/a	n/a	km	km	hr	rp*mile	as*mile	rt*mile	n/a
FAA FE Metric	*Fuel Burned (Tg)/Distance (Bill of km)*	FAA		x	x								x					
ICAO FE Metric	*Volume of Fuel/RTM*	ICAO		x	x										x		x	
CASFE	*Mass of fuel/(payload*GCD)*	ICAO		x	x				x	x		x						
ICAO CO2 Metric	*1/(SAR*RGF^β) with β = 0.24*	ICAO	x			x							x					
SAR	*Aircraft velocity/fuel flow*		x			x							x					
Fuel/ASM	*Load factor*(fuel/RPM)*	Lee (2000), Peeters	x				x								x			x
Payload Range Efficiency	*payload*range/fuel burnt*	Nangia (2006)	x		x				x	x			x					
Payload Fuel Energy Efficiency (PFEE)	*total payload*GCD/fuel energy consumed*	Hileman et al. (2008)		x			x		x	x		x						
Payload Fuel Energy Intensity (PFEI)	*fuel energy consumed/(payload*GCD)*	Hileman et al. (2013)		x			x		x	x		x						
FEu, FEi	*FEu = ASM/gal of fuel; FEi = RPM/gal of fuel*	McConnachie et al. (2013)		x	x										x	x		
ICCT Ratio Approach	$(Fuel/RPM)i^{adjusted}$	ICCT		x	x										x			
ICCT Deterministic Frontier Approach	$e^{\zeta_{it}}$	ICCT		x	x						x				x			
ICCT Stochastic Frontier Approach	$E[e^{\zeta_{it}}\|\varepsilon_{it}]$	ICCT		x	x						x				x			
3Di	*Accounts for flight inefficiencies, and applies weightings for different phases of flights*	NATS	x									x	x					
DOT Performance Goals, Indicators	*Aviation Fuel/RTM*	DOT		x	x										x		x	

Data Source Evaluation

*Default: System-wide Aggregation

Data Sources	Database Short Name	Database Name	Level of Disaggregation*				Region of Operations			Types of Operations				Metric Elements of Interest										
										Commercial Airlines		Other		Fuel		Productivity								
			By Region	By Carrier	By A/C Type	By Flight	Domestic		Int'l	US Carriers	Foreign Carriers	Military	GA	Fuel burn	Fuel Energy	Cargo weight	No. of Pax	Depart-ures	GCD	Distance Flown	Flight time	RPM	ASM	Cargo RTM	Load Factor
							50 States	Territories						kg	BTU	lb	n/a	n/a	km	km	hr	rp*mile	as*mile	rt*mile	n/a
As Operated/Database																									
Airlines for America	AER	Annual Economic Report					x	x	x	x				x			x	x		x		x	x	x	x
Airlines	10K	Airline Annual Report		x			x	x		x	x			x								x	x	x	x
BTS	NTS-421	Table 4-21 of *National Transportation Statistics*	x				x	x	x	x				x	x				x			x	x		x
	A1	Small Air Carriers: Schedule A-1		x			x	x	x	x									x		x				
	BlueBook	Air Carrier Industry Scheduled Service Traffic Statistics	x				x	x	x	x	x	x	x				x	x	x		x	x	x		x
	DB1BMarket	Airline Origin & Destination Survey: DB1BMarket		x		x	x	x		x									x	x					
	P-12a	Schedule P-12a		x			x	x	x	x				x											
	P-5.1	Schedule P-5.1		x			x	x	x	x				x							x				
	P-5.2	Schedule P-5.2		x	x		x	x	x	x				x							x				
	Airline Fuel	Airline Fuel Cost & Consumption	x				x	x	x	x				x											
	Monthly Fuel	Fuel Cost & Consumption					x	x	x	x				x											
	RAA	RAA: Commuter and Small Certificated Air Carrier Traffic and Capacity Statistics		x			x	x	x	x		x					x	x				x	x		x
	T-100	T-100 Segment (All Carriers)		x	x		x	x	x	x	x					x	x	x	x						
	T1	T1: Small Air Carriers		x			x	x	x	x						x	x		x						
	T2	T2: U.S. Air Carrier TRAFFIC And Capacity Statistics by Aircraft Type		x	x		x	x	x	x		x		x					x		x	x	x	x	
EIA	AEO	Annual Energy Outlook	x				x	x	x	x	x	x	x		x										
FAA/EPA	EPA GHG Report	Inventory of US Greenhouse Gas Emissions & Sinks (1990-2011)			x		x	x	x *(1 way)*	x	x	x	x	x	x					x					
FAA	ASQP	Airline Service Quality Performance System		x	x	x	x	x		x											x				
	ASPM	Aviation System Performance Metrics		x	x	x	x	x	x	x											x				
	FAA Forecast	FAA Aerospace Forecast	x				x	x	x	x	x		x	x			x	x		x	x	x	x	x	x
	GA & Airtaxi	General Aviation & Air Taxi Activity & Avionics	x		x		x	x					x	x							x				
	TFMCS	Traffic Flow Management System Counts		x	x	x	x	x	x	x	x *(Canadian)*	x	x					x		x	x				
	TAF	Terminal Area Forecast	x				x	x	x								x	x							
Oak Ridge National Laboratory	TEDB-9.2	Table 9.2 of Transportation Energy Data Book					x	x	x	x	x				x							x	x	x	x
	TEDB-9.3	Table 9.3 of Transportation Energy Data Book					x	x	x				x		x										
CFDR *(potentially for V&V, but not for reporting)*			x	x	x	x				x				x		tbd	tbd	x	x	x	x	tbd	x	tbd	tbd
COD *(optional)*			x		x	x	x	x	x	x	x			x				x	x						x
As Operated/Analysis Tool																									
EuroControl	BADA	Base of Aircraft Data				x								x						x	x				
FAA	AEDT/BADA	Aviation Environmental Design Tool				x								x							x				
Lissys	Piano-5	Project Interactive Analysis and Optimization aircraft design and				x								x		x				x	x				