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Sharing Airspace: Simulation of Commercial Space Launch Impacts on Airlines and Finding Solutions

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Sharing Airspace: Simulation of Commercial Space Launch Impacts on Airlines and Finding Solutions*

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Introduction

- Lack of quantitative estimates of the impacts of commercial space activities on airlines.
- Impacts of commercial space activities on commercial aviation gaining more visibility.
- Airlines apprehensive about the immediate negative effects in terms of
  - Time delays
  - Uncertainties
  - Costs
- Solutions for a fair and equitable integration of commercial space and commercial aviation to benefit all are required.
- Our research fills the need for simulation models to analyze the potential economic impacts on airlines, but also to identify solutions.

Selected Literature Review

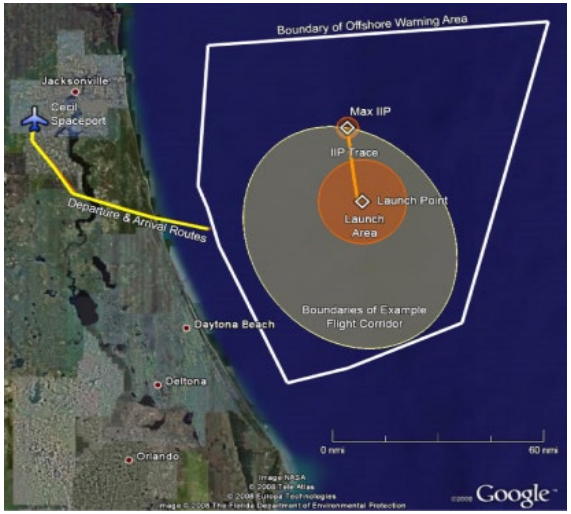
- Gonzales and Murray (2010)
  - Examine aircraft buffer zone/ground buffer zones for reusable suborbital rockets in relation to probability of failure, etc.
- Mazzotta and Murray (2015)
  - Discuss development/testing of the FAA's Space Data Integrator (SDI) system.
- Srivastava, St. Clair, Zobell, and Fulmer (2015)
  - Propose a two-step approach to estimate impact of space launch or reentry on airspace; estimates extra distance and delay of impacted flights; operational cost index of delay (ground and airborne).
- Young, Kee and Young (2015)
  - Present two sets of fast time simulation scenarios to demonstrate benefits of one proposed ATC procedure over current/assess impacts to NAS.

Selected Literature Review

- Tompa, Kochenderfer, Cole and Kuchar (2015)
  - Use Markov decision process model to investigate the optimal aircraft rerouting strategies/two-stage to orbit vehicle launched from Cape Canaveral.
- Colvin and Alonso (2015)
  - Simulate the effects of compact envelopes vs traditional class of hazard areas.
- Luchkova, Kaltenhaeuser, and Morlang (2016)
  - Construct simulation model to generate aircraft hazard areas in European airspace along conceptual SpaceLiner flight trajectory; uses shuttle accident debris data.
- Srivastava (2018)
  - Increase transparency and collaboration in integration of new entrants into NAS by enabling instantaneous assessment of the impact of blocking airspaces using a what-if analysis paradigm.

Methodology: Simulation Approach

- Simulation Model – Cecil Air and Space Port, Jacksonville, FL
  - Utilized the Jeppesen Total Airspace and Airport Modeler (TAAM) with Performance Data Analysis and Reporting System (PDARS) data
    - Baseline represents existing NAS conditions including airspace sectors and air traffic routes
    - Launch models represent scenarios of integrating commercial space operations in the NAS using the “Concept Z” profile with Virgin Galactic White Knight and SpaceShip Two
      - Horizontal take-off of mated craft
      - Launch of Spaceship Two above 40,000ft within TFR area



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Methodology: Simulation Approach

- Cecil Air and Space Port, Jacksonville, FL (assumed launch at 10 AM)
  - Scenario 1 – Complete TFR with airspace blocked from 8AM to 12PM
    - Discussions with Cecil revealed airspace shall be cleared two hours before and two hours after launch.
  - Scenario 2 – Complete TFR with airspace blocked from 9AM to 10:30AM
    - This assumes the airspace has been safely cleared within 30 minutes of launch based on a conversation with ZJX.
  - Scenario 3 – Complete TFR with airspace blocked from 9AM to 11AM
  - Scenario 4 – No Corridor TFR with airspace blocked from 8AM to 12PM
    - Carrier aircraft (White Knight) with mated SpaceShip Two is treated as an aircraft per ZJX.
- The simulation covers the worst-case *air traffic* scenario of a launch at 10AM, however airspace agreement indicates that launches shall take place before 9:00AM.

Simulation Scenario 1, 2, 3, 4: Cecil Air and Space Port

- Scenario 1 – Complete TFR with airspace blocked from 8AM to 12PM
- Scenario 2 – Complete TFR with airspace blocked from 9AM to 10:30AM
- Scenario 3 – Complete TFR with airspace blocked from 9AM to 11AM
- Scenario 4 – No Corridor TFR with airspace blocked from 8AM to 12PM

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Methodology: Simulation Approach

- Simulation Model – Cecil Air and Space Port, Jacksonville, FL
  - Only *primary* effects on airline routes were examined.
  - Per ZJX, during launch activities out of Cape Canaveral, flights are typically rerouted “funnel fashion” down the Florida peninsula.

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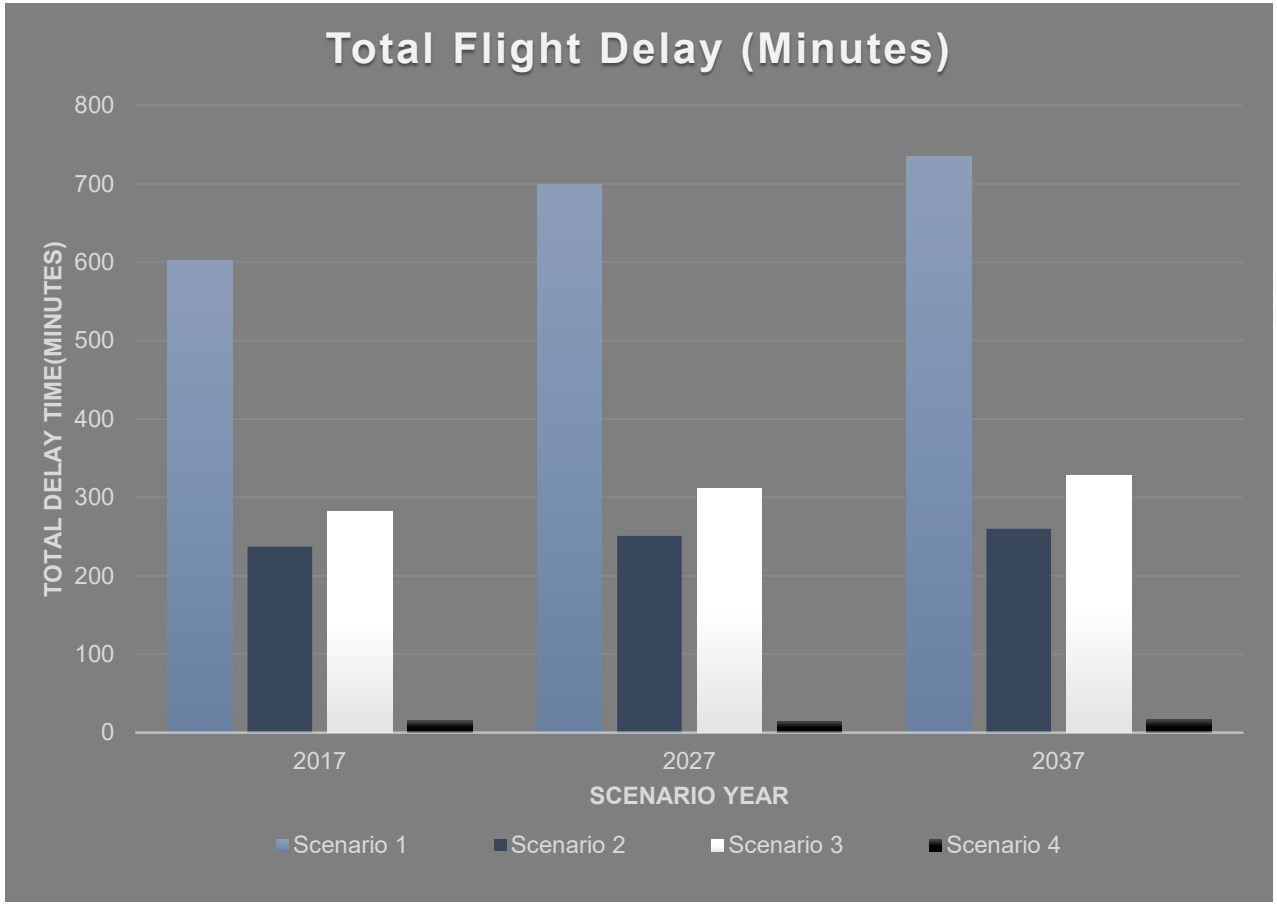
TAAM Simulation Set-Up

Scenarios	May 2, 2017	2027	2037
Baseline	Actual Air Traffic	Forecasted Air Traffic	Forecasted Air Traffic
Cecil Launch	Simulated Air Traffic	Forecasted Air Traffic	Forecasted Air Traffic

- May 2, 2017 represents the busiest air traffic conditions.
- Future air traffic volume estimated using FAA forecast data for the number of IFR flights handled by both ZJX and ZMA Air Route Traffic Control Centers (ARTCC). Air traffic volume was estimated to grow 15% from 2017 to 2027, and 28% from 2017 to 2037.
- Simulation is based on a single launch.
  - *Note:* Cecil Spaceport Launch Site Operator Renewal Application (LSO 09-012) used forecast of 52 launches per year (48 Concept X and 4 Concept Z).

Simulation Preliminary Results



- Flight delays can be used to understand the impact on commercial airline operations.
- Under current ATC procedures, impact is expected to increase with air traffic.
- Each column represents the impact of one launch.
- Worst case single delay was 12.28 minutes under Scenario 1.

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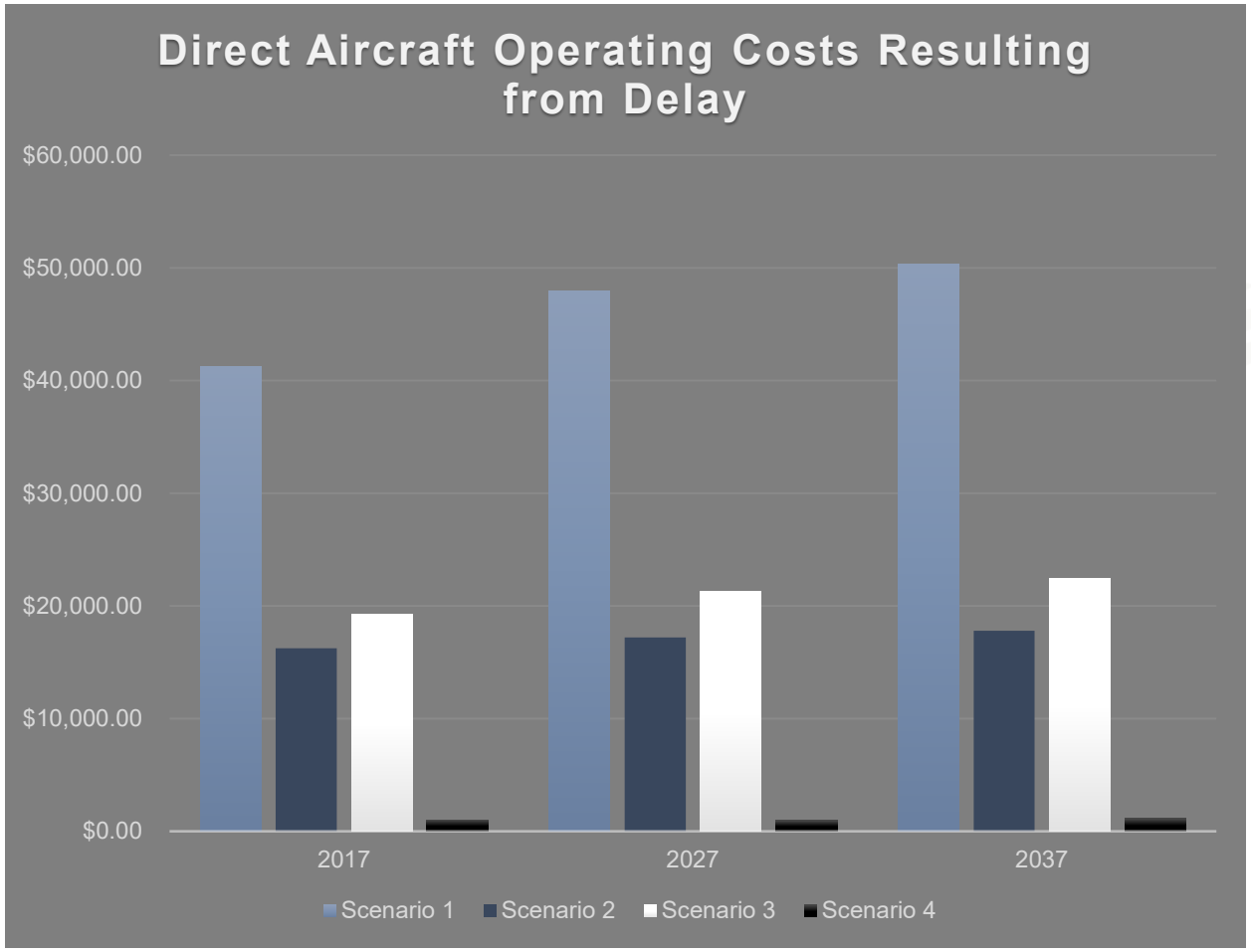
Simulation Preliminary Results



- Direct aircraft operating costs based on Airlines for America (A4A) passenger carrier delay costs (per block minute) of $68.48 average in 2017
  - Crew
  - Fuel
  - Maintenance
  - Aircraft ownership
  - Other
- Each column represents the impact of one launch.

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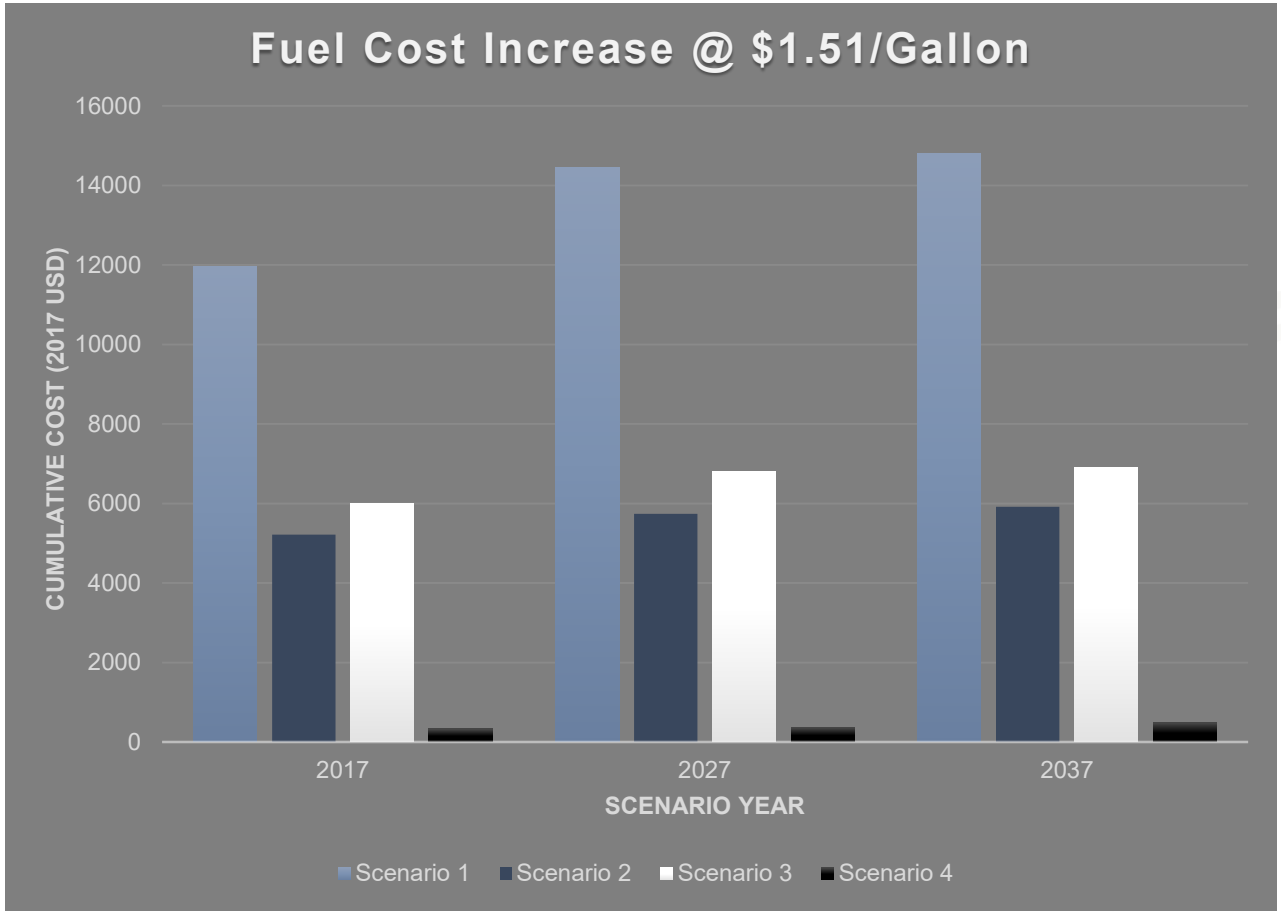
Simulation Preliminary Results



- Fuel costs only for affected flights
  - TAAM Dynamic Fuel Option was used.
- Jet fuel price for May 2, 2017 was used (Baseline).
- Each column represents the impact of one launch.

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Summary Remarks

- Commercial space activities impact commercial aviation.
  - Preliminary results for Concept Z indicate impacts to airlines can be alleviated by reducing the duration of airspace closure and/or not closing flight corridor.
  - As more data become available, airspace closures in terms of time and area will be fine-tuned for more efficient, effective, and safe integration.
  - Best solutions may be a hybrid of modifying airspace closure dimensions/shapes, coupled with reduction of the airspace closure duration.
- Impacts vary depending on spaceport location, launch time, & launch vehicle.
  - For example, earlier research for vertical launch of Atlas out of Cape Canaveral revealed longer delay time and higher costs.
- Negative impacts may be greater if no advanced warning is provided, i.e., unexpected debris from a flight anomaly may result in longer closures.

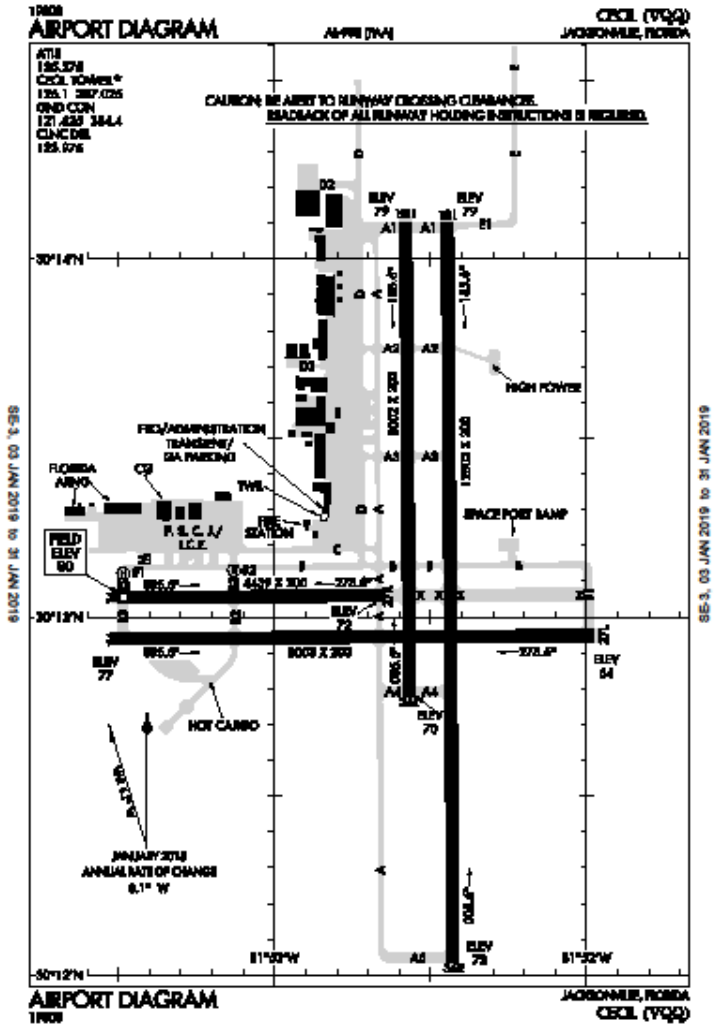
Future Research

- Future research should include analyses of
  - Impacts to other key stakeholders, such as airports.
  - Secondary effects on flights not directly impacted by the TFR.
  - Direct and indirect consequences of launch/return activities.
  - Consequences of forecasted increase in launch and return activities as well as changes to FAA procedures (simulation based on current FAA procedures).
  - Other spaceports with alternate launch vehicles.

Questions?
Thank you for your time.

View from VSS Unity's tailcone at 43,000 ft.
Source: www.virgingalactic.com

Cecil Air and Space Port



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Air Traffic – Normal vs Launch Activity

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