From:	Thomas.Braun@faa.gov
To:	katherine.branham@faa.gov
Cc:	Thomas.Braun@faa.gov
Subject:	FW: Camden Ec study for pops on Cumberland Island
Date:	Thursday, November 08, 2018 5:01:16 PM
Attachments:	image001.png image002.png image003.png image004.png image005.png

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From: Braun, Thomas (FAA)
Sent: Wednesday, October 31, 2018 4:46 PM
To: Murray, Daniel (FAA) <Daniel.Murray@faa.gov>
Cc: Jackson, Stewart (FAA) <stewart.jackson@faa.gov>; Underwood, Pam (FAA) <Pam.Underwood@faa.gov>; Zee, Stacey (FAA) <Stacey.Zee@faa.gov>; Searight, Howard (FAA) <Howard.Searight@faa.gov>; Braun, Thomas (FAA) <Thomas.Braun@faa.gov>
Subject: RE: Camden Ec study for pops on Cumberland Island

Dan,

For an F9 type of rocket with applicable POFs, yes greater than 200 people would start giving Camden issues with respect to Ec (1E-04) at certain azimuths.

Assuming the people are located where the cottages are, flying south would reduce the risk due to the lower number of cottages at those southern azimuths.

I believe Camden would have a difficult time flying with 300 people on the island.

Keep in mind, individual risk could still be an issue resulting in the need for evacuation or road blocks.

Note, a smaller vehicle (i.e. Rocket Lab) would reduce the casualty area, but the reliability would be less (increasing the POF).

I believe slide 34 below is a good summary for Camden.

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From: Murray, Daniel (FAA)
Sent: Wednesday, October 31, 2018 4:09 PM
To: Braun, Thomas (FAA) <Thomas.Braun@faa.gov>
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Subject: RE: Camden Ec study for pops on Cumberland Island

Tom,

Thanks for sending this along. I apologize I did not have a chance to call you back these past couple of days.

From your results, it appears safe (and more simple maybe) to say that, knowing things will vary depending upon what exactly is launched (for Pf, debris list, azimuth, etc), it appears that somewhere around 200 people or so on the island is where they could start to have trouble making Ec. That would require them to fly a more southerly azimuth (over big Cumberland) or find a customer with a demonstrated high reliability. Upwards of 300 people, they could have a hard time flying at all. Would you agree with that?

Thanks,

Dan

Dan Murray
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From: Braun, Thomas (FAA)
Sent: Wednesday, October 31, 2018 3:46 PM
To: Murray, Daniel (FAA) <Daniel.Murray@faa.gov>
Cc: Braun, Thomas (FAA) <Thomas.Braun@faa.gov>; Jackson, Stewart (FAA) <stewart.jackson@faa.gov>
Subject: FW: Camden Ec study for pops on Cumberland Island
Importance: High

Dan,

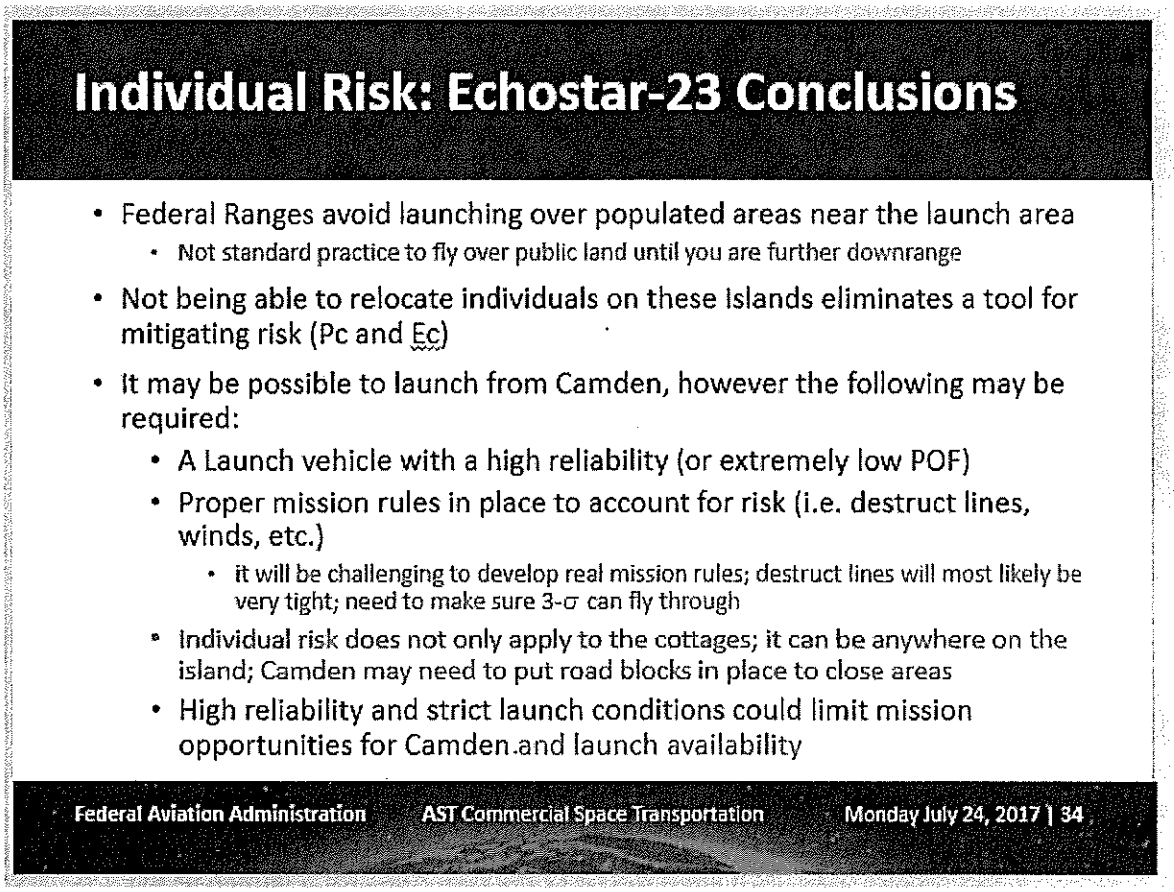
I briefed Stewart on the slides and results. If you would like to sit down to discuss the results, please let me know when you may have time.

Enclosed is the excel file documenting the Ec study for varying population (and POF) on Cumberland Island.

- I have also included the Camden Individual risk presentation I did in July of 2017. The populations used were 110 people in 55 cottages (2 per cottage).
    - Be aware that the individual risk analysis demonstrated that **individual risk could be a problem, specifically for the malfunction turn (MFT) response mode.**
    - Refer to slides 33 and 34 in the presentation for conclusions
        - Note the upper reliability number of 1% quoted below may not be the upper threshold.

Individual Risk: Echostar-23 Conclusions

- Vehicle Reliability is very important! (between 0.1% and 1%)
- OT and LOT trajectories (without dispersions) indicated Pc results were within limits
    - Adding dispersions would most likely extend Pc (unsheltered) contours in downrange and crossrange
- MT trajectories (without dispersions) indicated Pc results were NOT within limits
    - Large Ec and Max Pc were observed
    - MT trajectories extend farther downrange due to off-nominal behavior
    - MT trajectories used were based of mission rules for a launch at KSC
        - Proper mission rules for Camden would be required to protect individuals on the Islands
- Winds used for assessment were average winds, not worst case winds



The acceptable Ec risk is a function of the trajectory azimuth, POF, casualty area and the population on the island.
For this analysis, the casualty area was held constant. The casualty area was a result of an F9 debris list.

The analysis was done by varying the number of people on the 55 cottages located on Cumberland Island. The populations varied as follows:

- 2 people per cottage * 55 cottages = 110 people
- 4 people per cottage * 55 cottages = 220 people
- 6 people per cottage * 55 cottages = 330 people

The analysis considered the following assumptions:

- Data from the F9 Echostar-23 (due east) Mission translated to Camden launch pad and rotated to the appropriate azimuth
- MFT trajectories were based on mission rules for a GTO launch at KSC
  - I did not use the trajectory data provided by Camden.; SpaceX data was deemed more realistic
- December wind (worst case seasonal wind)
- POF (4.7% first stage)
  - MFT (2.75%)
  - OT (1.13%)
  - LOT (0.08%)

- Cumberland Island population only
- No RTLS
- No dispersions (due to problems translating F9 Echostar-23 .mcov format data)
- Risk from ships is not included in the Ec number.
- Overflight risk not included
    - The most recent Ec for the F9 due to overflight of Europe is 8E-06
    - The most recent Ec for the F9 due to overflight of Africa (GTO missions) is 1E-06

From Camden's application, here are the trajectories for the following azimuths. My analysis considers 85, 100 and 120 degrees – this would be 1E-06 for overflight of Africa.

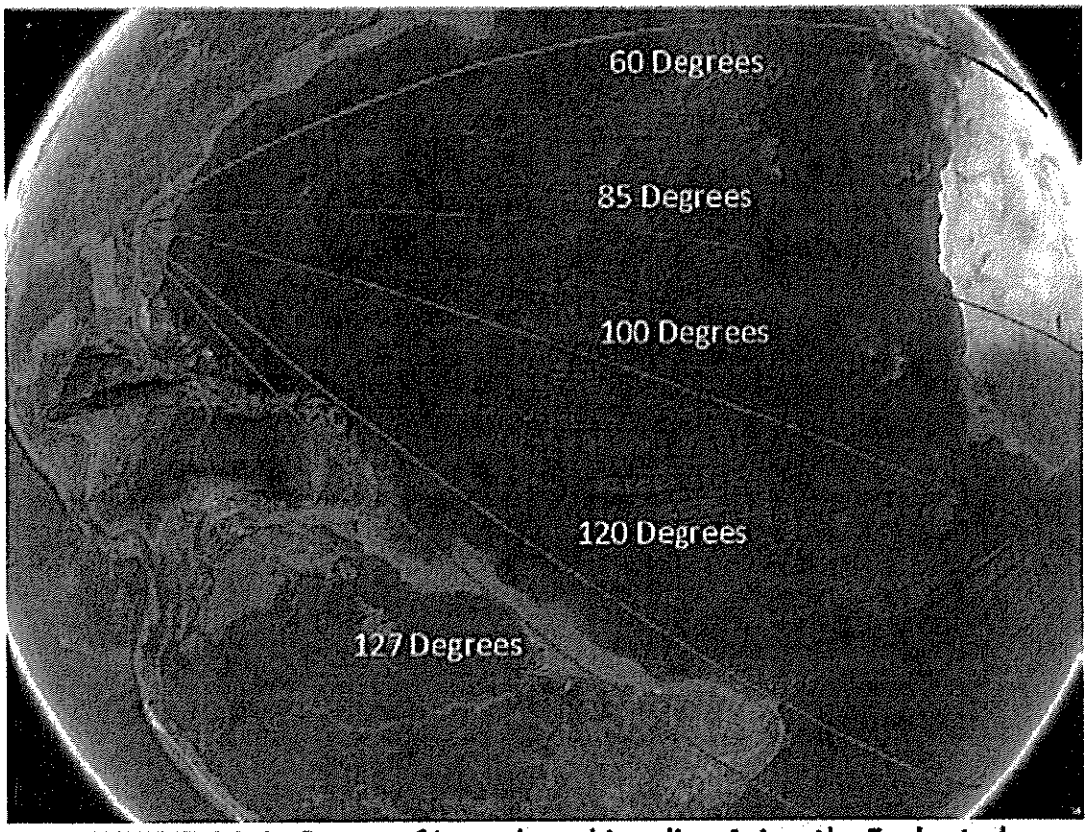


EXHIBIT A2-9. Range of Launch and Landing Azimuths Evaluated

Although Camden provides results for all of the azimuths, Camden only provided data for only the 100 deg azimuth. The POF used by Camden was 10% (30% OT, 30% LOT, 40% MFT).

Below is a comparison of results between Camden and the FAA. FAA is typically 10E-06 larger. Note, POF, casualty area and trajectories will be different. See slide 37.

1st Stage Ec Results: Echostar-23
AST Ec only include Cumberland Islands

Echostar-23 Trajectory	OT Ec	LOT Ec	MT Ec	Total Ec
60° azimuth	3.45E-06	8.33E-06	4.09E-05	5.268E-05
75° azimuth	6.28E-06	1.28E-05	6.32E-05	8.228E-05
85° azimuth	4.98E-06	1.04E-05	5.04E-05	6.578E-05
100° azimuth	3.02E-06	6.55E-06	3.23E-05	4.187E-05
120° azimuth	2.18E-06	4.04E-06	1.97E-05	2.592E-05
127° azimuth	2.05E-06	4.41E-06	2.25E-05	2.896E-05

Camden Ec Results x 1E-04 ⟶ Uses different POF, SV, CA

Operation Type	Trajectory Azimuth	Stage 1 Monte Carlo
Launch	60	0.43
	85	0.70
	100	0.53
	120	0.28
	127	0.16

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I spoke with Tom Ricketson regarding the Falcon 9. The following response modes are modelled for launch :

- OT On-Trajectory
- LOT Loss of Thrust
- MFT Malfunction Turn (tumble turn)
- RA Random Attitude
- IA Incorrect Azimuth

Currently, the total POF for a F9 is 3.9% (0.039). This is modelled as 1.6% (0.016) for first stage and 2.1% (0.021) for second stage.
This sums up to 3.7%. The remaining 0.2% is due to staging and the fairing jettisons.

For the first stage, the percentages break down to the following:

- OT 0.016 * .566
- LOT 0.016 * .038
- MFT 0.016 * .324
- RA 0.016 * .063
- IZ 0.016 * .009

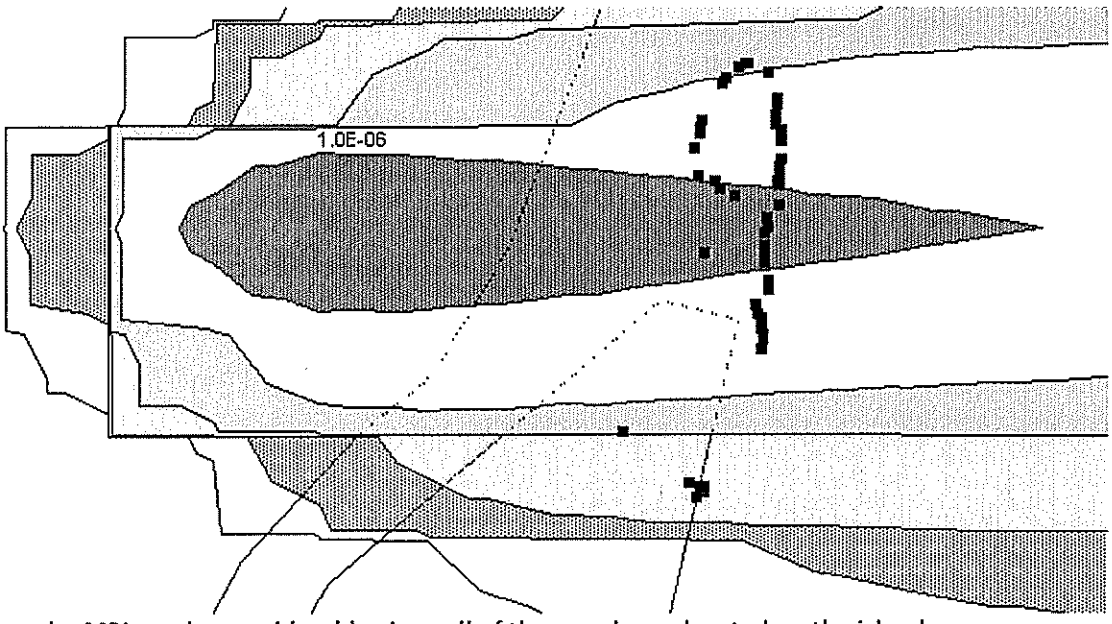
1.0

To assess population sensitivity with POF sensitivity, within the excel file refer to columns:

- I (Ec) and J (POF) 4.7% 1st stage POF (Original analysis)

- L (Ec) and M (New F9 POF) 1.6% 1st stage POF
- O (Ec) and P (Part 420 POF) 10% 1st stage POF (from Appendix C Part 420)

I believe the 85 degree azimuth case would be most representative of a trajectory flying over populated regions on the Island. See image below.
Note, the 100 deg and 120 deg cases seem to avoid most of the cottages. Perhaps that is why Camden is providing data for the 100 deg azimuth case.
Other Individual risk plots are in the July 2017 presentation.



Note, the MPL can be considerable given all of the people are located on the island.

The excel spreadsheet indicates that risk is within the 1E-04 constraint for the 110 population.

For the 220 population, the 85 deg azimuth, POF=4.7%, (Ec = 1.37E-04) could violate the 1E-04 constraint (if dispersions, overflight and the RA and IA response modes are included)
For the 220 population, the 85 deg azimuth, POF = 10%, (Ec = 2.49E-04) will violate the 1E-04 constraint
For the 220 population, the 100 deg azimuth, POF = 10%, (Ec = 1.58E-04) violated the 1E-04 constraint.

For the 330 population, the 85 deg azimuth, POF = 4.7%, (Ec = 2.05E-04) will violate the 1E-04 constraint
For the 330 population, the 85 deg azimuth, POF = 10%, (Ec = 3.73E-04) will violate the 1E-04 constraint
For the 330 population, the 100 deg azimuth, POF = 10%, (Ec = 2.36E-04) will violate the 1E-04 constraint
For the 330 population, the 120 deg azimuth, POF = 10%, (Ec = 1.48E-04) will violate the 1E-04 constraint

The current F9 POF would make all of the Ec violations above go away. Within the excel file, refer to columns L (new Ec) and M (new POF) for POF sensitivity.

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