

Space Weather Impacts and Needs for Future Commercial Space Operations



Federal Aviation
Administration



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**FAA/Office of Commercial Space Transportation (AST)
Space Transportation Development Division**

Space Weather Workshop (SWW), April 24-27, 2012



Agenda

- FAA/AST's Background and Authority
- Commercial Space Transportation (CST) Activity
- Emerging Science Payload Market
- SWx Considerations for CST Operations
- How to Prepare for Future Commercial Spaceflight
- FAA/AST Space Weather Initiatives
- Conclusion



Background

- The U.S. space program today has 3 sectors:
 - Civil
 - Military
 - **Commercial**
- The commercial sector was created in 1984 with the passage of the Commercial Space Launch Act; and
- Regulatory oversight for the commercial sector was delegated to the Associate Administrator for Commercial Space Transportation (AST).
- Today, AST makes up one of the three lines of business within the FAA.

DOT Authority: *Title 51 U.S. Code* *Subtitle V, Ch. 509*

- **Protect** the public, property, and the national security and foreign policy interests of the U.S
- Oversee and coordinate **commercial launch and reentry operations** including those with **crew and space flight participants**.
- Issue **permits and licenses** and transfer licenses authorizing those operations.
- **Promote economic growth** and entrepreneurial activity through the use of the space environment for peaceful purposes.
- **Encourage the U.S. private** sector to provide launch vehicles, reentry vehicles and associated services.
- **Facilitate the strengthening and expansion** of U.S. space transportation infrastructure.

What types of activities is AST involved in?

Launch Site Licenses
Launch/Reentry Licenses
Experimental Permits
Safety Inspections
Safety Approvals
Regulations/Guidelines



Sea Launch



Launch Sites



Expendable Launch Vehicles



Reusable Launch Vehicles



Current Number of Commercial Launch Licenses, Experimental Permits, and Launch Site Licenses

- **Active Launch Licenses:**
 - Since 1984 -205 successful launches
 - 15, #15 launch license issued to Space X for its Falcon 9, ELV
- **Active Experimental Permits:**
 - Since 2004 - 22 Successful experimental permit flights
 - 1, Blue Origin
- **Active Launch Site Operator Licenses:**
 - 8, Kodiak, California, Mojave, Spaceport America, Oklahoma, Mid-Atlantic, Cecil Field, and Florida
- **Commercial Astronaut Wings:**
 - 2, Michael Melville and Brian Binnie of Scaled Composites
 - Major milestone officially recognized by AST

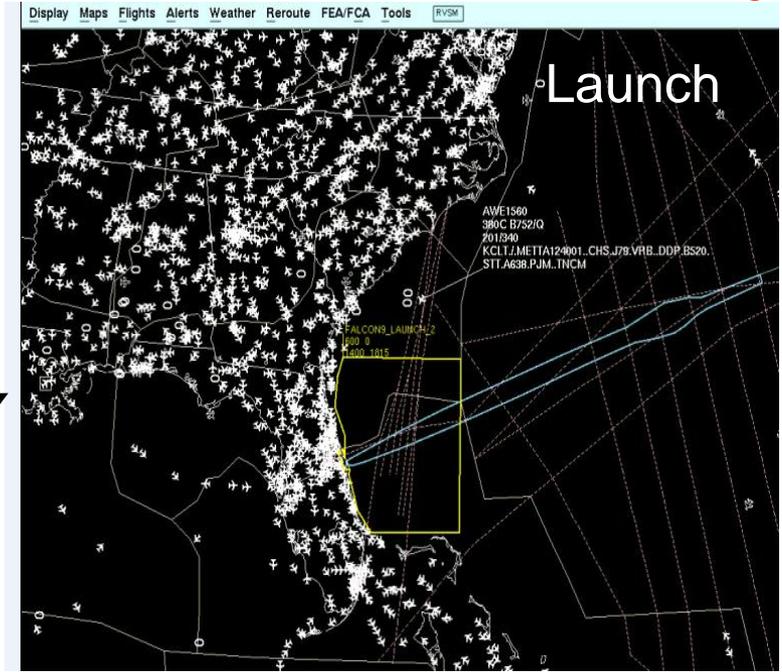
FAA Integrated Efforts – *Launch/Reentry*

For a licensed launch or reentry:

- Flight safety analysis of a proposed launch or reentry vehicle from a specific launch or reentry site is performed
- ATO provides deconfliction of air traffic
- Other USG entities provide deconfliction of sea traffic, as well as launch and range support and collision avoidance

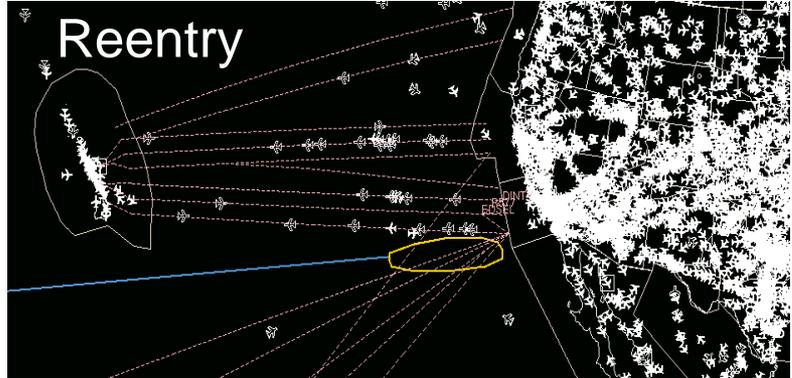
Example: East Coast (Florida) Launch

- 3+ hour launch window
- Affected nearly 200 flights
- Ensured safety of the public



Example: West Coast Reentry

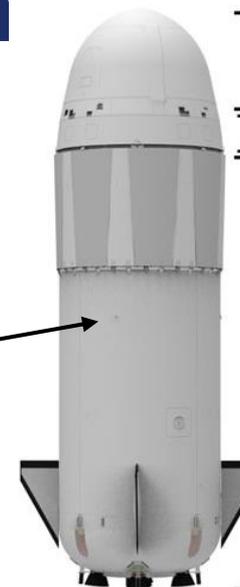
- Analysis allowed for smaller hazard area
- Affected 41 flights
- Moved activity to less dense air routes
- Ensured safety of the public



Suborbital/Orbital Reusable Launch Vehicles (RLVs) – Space Tourism



Virgin Galactic's WhiteKnightTwo and VSS Enterprise



Blue Origin's New Shepard

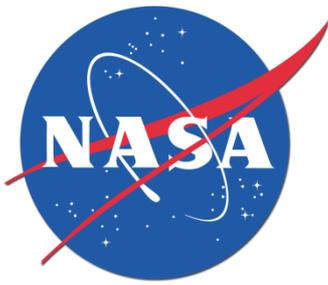


XCOR's Lynx



Launch Aircraft

Stratolaunch Systems



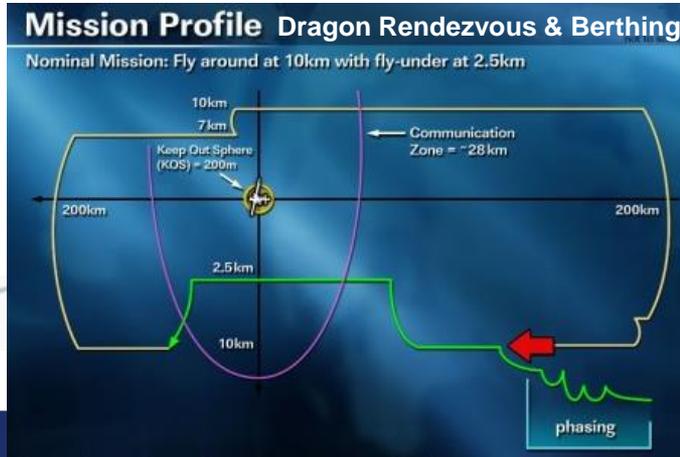
Orbital Reusable Launch Vehicle Activity – Commercial Orbital Transportation Services and Commercial Resupply Services Contract Award



Dragon Capsule



Cygnus Spacecraft



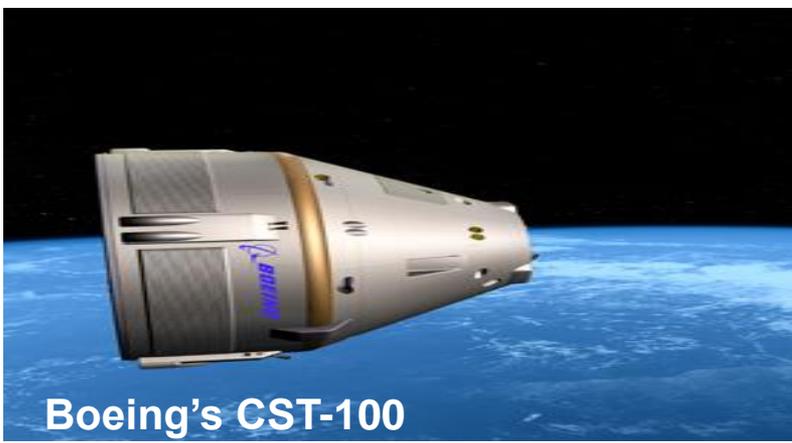
SPACEX

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SWW, April 24, 2012



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Orbital Reusable Launch Vehicle Activity (cont.) – Commercial Crew Development Program (CCDEV)



Boeing's CST-100



Space-X Dragon Capsule



Blue Origin Crew Transportation System



Sierra Nevada Corporation Dream Chaser

Suborbital/Orbital Science Payload Market

Flight Opportunities Program –

- Integrate and fly technology payloads on commercial suborbital reusable platforms that carry payloads near the boundary of space

Seven companies selected:

- Armadillo Aerospace, Heath, Tx.
- Near Space Corp., Tillamook, Ore.
- Masten Space Systems, Mojave, Calif.
- Up Aerospace Inc., Highlands Ranch, Colo.
- Virgin Galactic, Mojave, Calif.
- Whittinghill Aerospace LLC, Camarillo, Calif.
- XCOR, Mojave, Calif.

• Virgin Galactic

- Southwest Research Institute has signed up two payload specialists to conduct biomedical monitoring, atmospheric imaging, and microgravity planetary regolith experiments.

• SpaceX

- Proposing to use Dragon for research applications independent of the ISS.
- DragonLab, a free-flying version of its spacecraft designed to carry a variety of experiments that can be returned to Earth.
- The company has booked two DragonLab flights on its launch manifest, in 2012 and 2013.

Space Weather (SWx) Considerations for Future Commercial Space Operations

SWx impacts will differ for suborbital vs orbital flight & are dependent on altitude, launch latitude, orbital inclination, duration of mission, solar cycle, & solar activity

- Sub-orbital Regime
 - Space Flight Participants: Probably one-time, short duration exposure
 - Crew: Repeated or frequent short duration exposure

- Orbital Regime
 - Longer duration and increased radiation exposure for crew and space flight participants
 - Crew: Repeated exposure
 - Radiation exposure would depend on inclination, Vehicle Shielding, Vehicle orientation, & location within vehicle
 - Vehicle Components and length of time in Orbit
 - Single Event Effects on electronics
 - Material degradation

For human spaceflight, launch operator is responsible for understanding risks associated with launch and reentry of the vehicle and informing crew and spaceflight participants of these risks

Way forward: How to prepare for future commercial space transportation (human spaceflight)?

- **Educate AST & Launch Operator on SWx risks:**
 - Develop in house checklist for events/parameters that could impact suborbital and orbital flights
 - Provide information to the launch operator on where to obtain SWx information
- **Continue collaboration/partnering with NOAA SWPC, NASA GSFC & NASA LaRC, and the OFCM**
 - Initiate opportunities for collaboration/partnering with other government agencies such as NASA/JSC Space Radiation Analysis Group (SRAG), DoD's Air Force Weather Agency, AFRL, & NRL
- **Work with the space weather providers to identify products that could be useful for commercial space transportation**
- **Educate SWx Community on commercial space activities and opportunities for furthering research/validation of space weather**

Commercial Space Transportation Initiatives

Center of Excellence – Commercial Space Transportation

<http://www.coe-cst.org/>

TASK 186 - *Mitigating threats through space environment modeling/prediction*

•**Goal:** *Predict the environmental conditions needed for safe orbital, sub-orbital, re-entry, descent, and landing*

•**Objectives:** *Develop a “weather” (terrestrial weather and space weather) prediction model extending from Earth’s surface to the edge of space (~600km)*

Space Transportation Infrastructure Grants Program:

FY 2012 – Federal Register Notice published 3/9/12

Submission Open Period March 8, 2012

Submission Closes May 11, 2012.

<http://www.gpo.gov/fdsys/pkg/FR-2012-03-09/pdf/2012-5706.pdf>

Conclusions

- Commercial Human Space Flight -- is well underway.
- Congress, through the Commercial Space Launch Amendments Act, has directed the FAA to “encourage, facilitate, and promote” this new activity in a way that continuously improves its safety through regulation and licensing activities.
- Critical to safety is integration of comprehensive, relevant, timely space weather information
- AST is committed to doing its part to enable this exciting new industry but needs to partner and collaborate with the space weather community to ensure the success of the industry.



QUESTIONS?



Background Slides



Types of Licenses

- Launch License (for Expendable Launch Vehicles).
 - *Launch-specific license* authorizes a specific launch or multiple launches with nearly identical parameters (vehicle design, launch location, trajectory, payload, etc.).
 - *Launch Operator license* authorizes launches of range of payloads and trajectories for a family of vehicles from the same site.
- Reusable Launch Vehicle (RLV) Mission Licenses.
 - *Mission-specific license* authorizes a licensee to launch and reenter one model (may authorize more than one RLV mission, but identifies each flight).
 - *Operator license* authorizes a licensee to launch and reenter any of a designated family of RLVs within authorized parameters, including launch sites and trajectories, transporting specified classes of payloads to any reentry site or other location designated in the license.
- Reentry Licenses.
 - *Reentry-specific license*.
 - *Reentry-operator license*.
- Launch or Reentry Site Operator License.
 - Authorizes operation of a launch or reentry site.

Active Launch Licenses: 15

Licenses	Company	Vehicles	Location	Expiration
LLO 11-078 (PDF)	Lockheed	Atlas V	VAFB	Dec. 20, 2016
LLO 01-064 (PDF)	Lockheed	Atlas V	CCAFS, FL	Dec. 13, 2016
LLS 11-075 (PDF)	Orbital	Taurus II	Wallops, VA	Aug. 04, 2012
LLS 11-077 (PDF)	Orbital	Taurus II	Wallops, VA	Sep. 01, 2012
RLS 11-002 (PDF)	SpaceX	Dragon Reentry Capsule	Pacific Ocean	May 24, 2013
LLO 04-069 (PDF)	Orbital	Pegasus	Reagan TS	Jul 22, 2014
LLO 00-048 (PDF)	BLS	Delta II	VAFB, CA	Jan. 02, 2015
LLO 00-051 (PDF)	Orbital	Taurus	VAFB, CA	Apr. 25, 2015
LLO 00-053 (PDF)	Orbital	Pegasus	VAFB, CA	Sep. 01, 2015
LLO 01-058 (PDF)	Orbital	Pegasus	Wallops, VA	Mar. 16, 2016
LLO 01-059 (PDF)	Orbital	Pegasus	CCAFS, FL	Mar. 17, 2016
LLO 01-060 (PDF)	BLS	Delta II	CCAFS, FL	Apr. 30, 2016
LLO 02-066 (PDF)	Energia	Zenit 3SL	Pacific Ocean	Jun. 21, 2016
LLO 01-062 (PDF)	BLS	Delta IV	CCAFS, FL	Sep. 05, 2016

15th License
LLS 12-079
Space X,
Falcon 9

Active Launch Site Operator Licenses: 8

Commercial Astronaut Wings: 2

Licenses	Operator	Site	Location	Expiration
LSO 02-007 (PDF)	Virginia Commercial Space Flight Authority	Wallops	VA	Dec. 18, 2012
LSO 01-005 (PDF)	Spaceport Systems International	VAFB	CA	Sep. 18, 2016
LSO 06-010 (PDF)	Oklahoma Space Industry Development Authority	Burns Flat	Oklahoma	Jun. 11, 2016
LSO 10-014 (PDF)	Space Florida	CCAFS	FL	Jun. 30, 2015
LSO 09-012 (PDF)	Jacksonville Aviation Authority	Cecil	Florida	Jan. 10, 2015
LSO 04-009 (PDF)	East Kern Airport District	Mojave	VA	Jun. 16, 2014
LSO 08-011 (PDF)	New Mexico Spaceflight Authority	SpAmerica	New Mexico	Dec. 14, 2013
LSO 03-008 (PDF)	Alaska Aerospace Development Corporation	Kodiak	AK	Sep. 24, 2013

FAA Commercial Astronaut Wings Issued: 2

Name	Vehicle	Mission	Max Altitude	Location	Flight Date
Michael Melvill	SpaceShipOne	Flight 15P	328,491 ft.	Mojave, CA	21 June 2004
Brian Binnie	SpaceShipOne	Flight 17P	367,442 ft.	Mojave, CA	04 October 2004

Permitted Launches: 22

Active Experimental Permits: 1

#	Date	Vehicle	Company	Site	Objective
22	Aug 24, 2011	PM 2	Blue Origin	West Texas	Flight Test
21	May 06, 2011	PM 2	Blue Origin	West Texas	Flight Test
20	Oct 25, 2008	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: Northrop Grumman Lunar Lander Challenge
19	Oct 24, 2008	MOD-1	Armadillo Aerospace	Las Cruces	Flight Test: Northrop Grumman Lunar Lander Challenge
18	Oct 24, 2008	MOD-1	Armadillo Aerospace	Las Cruces	Flight Test: Northrop Grumman Lunar Lander Challenge
17	Oct 24, 2008	Ignignokt	Scott Zeeb d/b/a TrueZero	Las Cruces	Flight Test: Northrop Grumman Lunar Lander Challenge
16	Oct 24, 2008	MOD-1	Armadillo Aerospace	Las Cruces	Flight Test: Northrop Grumman Lunar Lander Challenge
15	Oct 28, 2007	MOD-1	Armadillo Aerospace	Holloman	Flight Test: XPrize Cup Competition
14	Oct 28, 2007	MOD-1	Armadillo Aerospace	Holloman	Flight Test: XPrize Cup Competition
13	Oct 27, 2007	MOD-1	Armadillo Aerospace	Holloman	Flight Test: XPrize Cup Competition
12	Oct 27, 2007	MOD-1	Armadillo Aerospace	Holloman	Flight Test: XPrize Cup Competition
11	Oct 20, 2007	MOD-1	Armadillo Aerospace	Oklahoma	Flight Test
10	Jun 02, 2007	QUAD (Pixel)	Armadillo Aerospace	Oklahoma	Flight Test
9	Jun 02, 2007	QUAD (Pixel)	Armadillo Aerospace	Oklahoma	Flight Test
8	Apr 19, 2007	PM 1	Blue Origin	West Texas	Flight Test
7	Mar 22, 2007	PM 1	Blue Origin	West Texas	Flight Test
6	Nov 13, 2006	PM 1	Blue Origin	West Texas	Flight Test
5	Oct 21, 2006	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: XPrize Cup Competition
4	Oct 21, 2006	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: XPrize Cup Competition
3	Oct 21, 2006	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: XPrize Cup Competition
2	Oct 20, 2006	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: XPrize Cup Competition
1	Oct 19, 2006	QUAD (Pixel)	Armadillo Aerospace	Las Cruces	Flight Test: XPrize Cup Competition

Commercial/Government/Private and Proposed U.S. Launch Sites



Potential Space weather needs for commercial space operators in LEO

- Total dosage of charge particles
- Timing/duration of Proton events
- Changes in energetic particle densities
- Timing/duration of communication/navigation disruptions



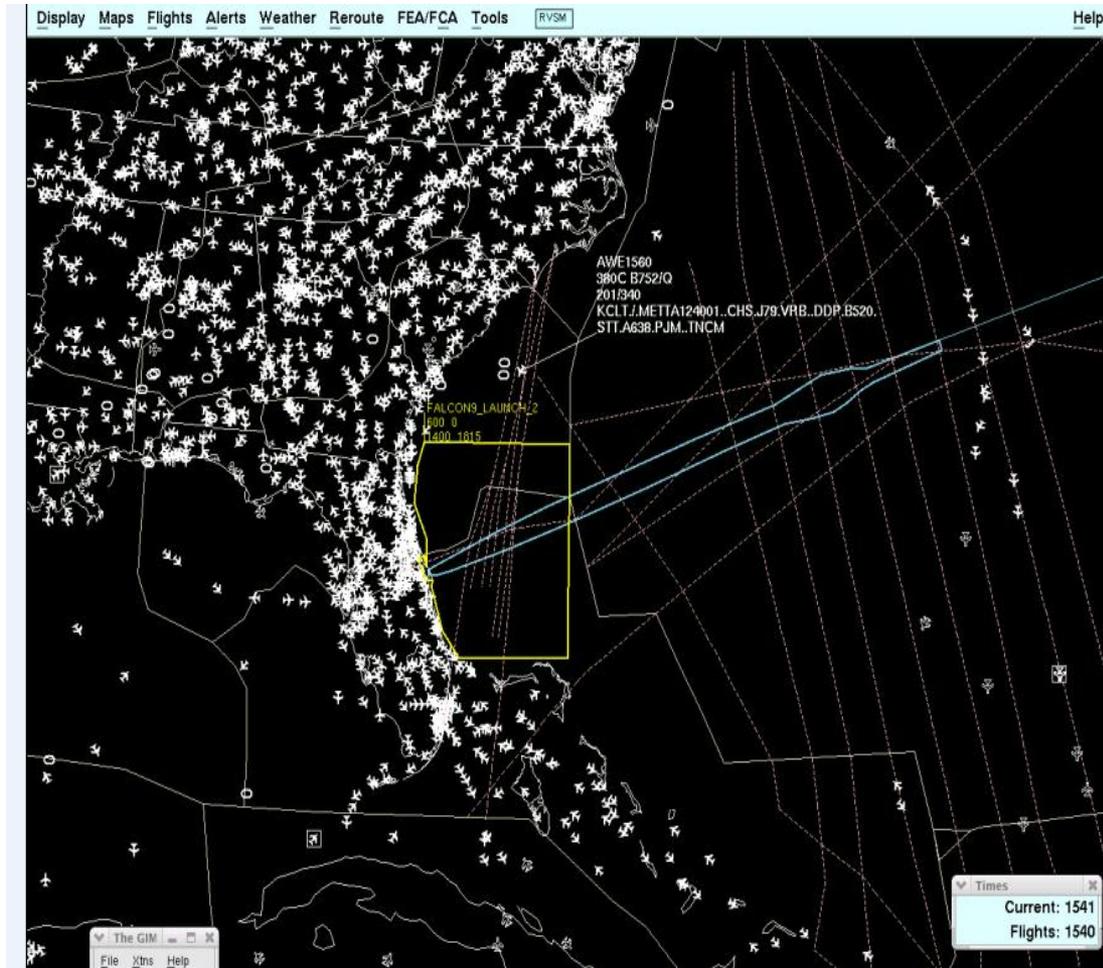
FAA Integrated Efforts – *Launch*

For a licensed launch:

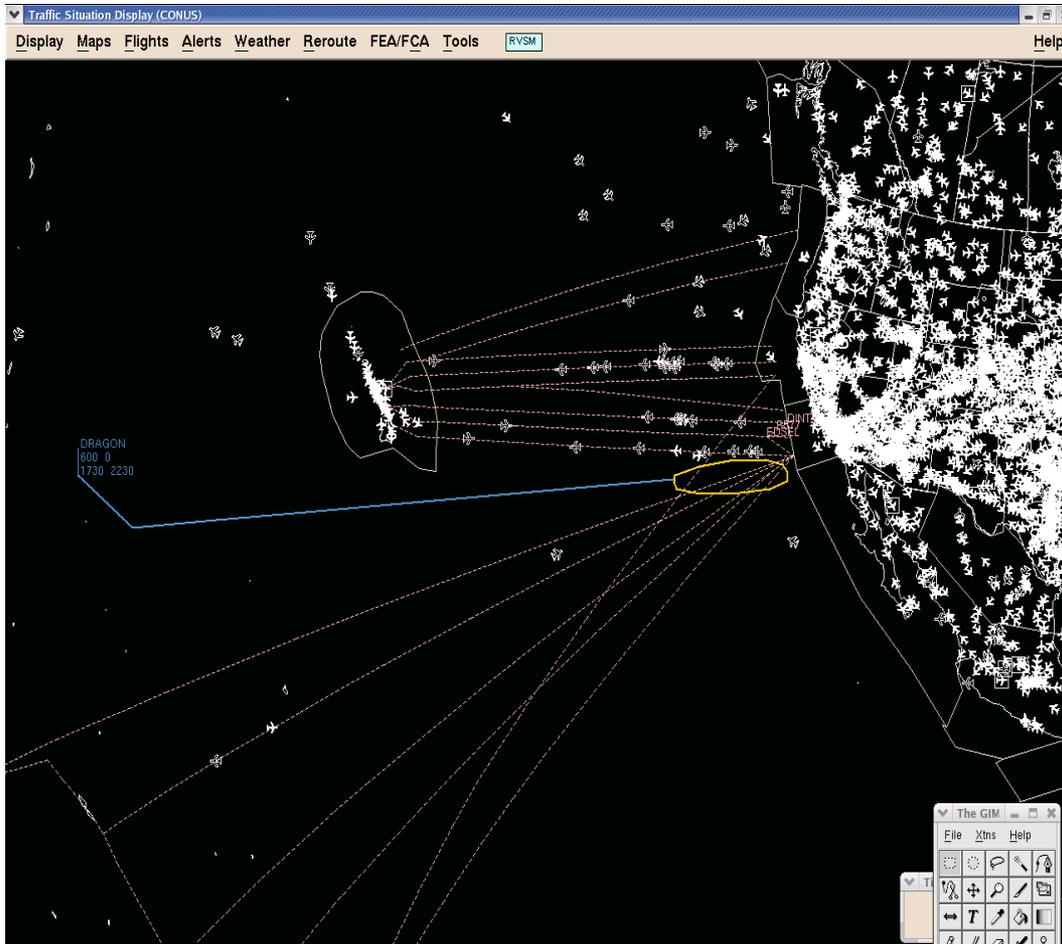
- AST performs flight safety analysis of a proposed launch vehicle from a specific launch site
- ATO provides deconfliction of air traffic
- Other USG entities provide deconfliction of sea traffic, as well as launch and range support and collision avoidance

Example: East coast (Florida) launch

- 3+ hour launch window
- Affected nearly 200 flights
- Ensured safety of the uninvolved public



FAA Integrated Efforts – *Reentry*



For a licensed reentry:

- AST performs a flight safety analysis of proposed reentry vehicle to a specific reentry area
- ATO provides deconfliction of air traffic
- Other USG entities provide deconfliction of sea traffic, as well as reentry support

What about On-Orbit?

- *The Secretary (DOT) has no authority to license or regulate activities that take place between the end of the launch phase and the beginning of the reentry phase, such as maneuvers between two Earth orbits or other non-reentry operations in Earth orbit; or after the end of a launch phase in the case of missions where the payload is not a reentry vehicle.*



- **For purposes of an ELV launch, flight ends:**

After the licensee's last exercise of control over its launch vehicle.

- For orbital, this is usually safing of the upper stage.
- For suborbital, impact.

- **For purposes of a RLV launch, flight ends:**

After the licensee's last exercise of control over its launch vehicle.

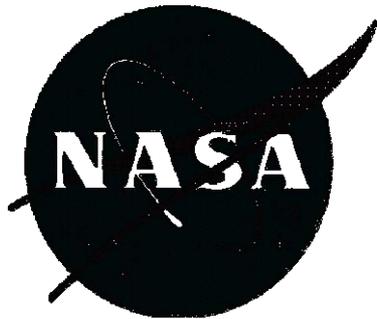
- For suborbital, upon landing when the vehicle comes to a stop and the vehicle is safed.
- For orbital, after deployment of a payload for an RLV having payload deployment as a mission objective; or
 - Upon completion of the first sustained, steady-state orbit at its intended location for an RLV not having payload deployment as a mission objective.

NASA and FAA Approach to Human Safety

- NASA and FAA approaches to human safety are based on their respective missions
- Different missions lead to different approaches



- Regulator for a new, broad and varied industry
- Charged with allowing the industry to develop
- Focused only on the safety of public and spacecraft occupants (crew only)
- Mission success is launch customer's requirement
- Results in regulations that are more general and performance based



- Customer with a system level need (support ISS)
- Detailed system requirements
- NASA has its own requirements for the safety of its crews
- Willing and able to pay for top quality systems

Human Spaceflight Regulations – 14 CFR §460

- Phased approach in regulation of human space flight due to emerging commercial space industry
- Establishes requirements for crew and space flight participants (passengers) involved in private human space flight.
 - Applies to protection of the uninvolved public.
 - Enables passengers to make informed decisions about personal safety by requiring that the launch operator inform them of the risks associated with launch/reentry (informed consent).
 - Training for crew and space flight participants
 - Medical qualifications for crew
- *FAA is restricted from issuing regulations (Until October 2015) regarding vehicle design or operations unless:
 - There has been a serious or fatal injury or close call to crew or space flight participants during a licensed or permitted flight. After October 2015, the FAA may propose regulations without restriction.
 - Must take into consideration the evolving standards of safety in the commercial space flight industry.

*Recently extended moratorium is intended to allow the industry to mature before the FAA issues regulations covering passenger and crew safety