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Challenges and Opportunities Related to Landing the *Dream Chaser*® Reusable Space Vehicle at a Public-Use Airport

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Sierra Nevada Corporation's (SNC) Space Systems is developing the *Dream Chaser*® reusable space vehicle for NASA's Commercial Crew and Cargo Resupply Programs and a broad array of other viable customers. The Dream Chaser is an optionally-piloted lifting body vehicle that lands on a runway, similar to the Space Shuttle. Unlike the Space Shuttle, the Dream Chaser does not require any unique landing aids or specialized equipment as it uses all non-toxic propellants and industry standard subsystems. These features allow for immediate access to crew and cargo at wheels-stop. Requiring only 8,000 feet/2,400 m of runway for landing, the Dream Chaser is compatible with numerous public runways, both domestic and international. There are, however, unique and complex challenges associated with landing a reusable spacecraft on the runway of a public-use airport. The challenges and opportunities associated with landing the Dream Chaser at public airports are identified and addressed in this paper.

I. Introduction

The Sierra Nevada Corporation (SNC) *Dream Chaser*® is a unique, optionally-piloted lifting body vehicle designed to carry up to seven crew and/or cargo to and from low Earth orbit (LEO), including the International Space Station (ISS). The crewed and cargo design is capable of 3.5 days of independent flight with docking stays at the ISS of up to 210 days. ***Figure 1*** shows the Dream Chaser ISS mission concept of operations.

The Dream Chaser does not use any hazardous materials for operation; therefore, the Dream Chaser can land at any suitable runway (> 8,000 feet/2,400 meters long) around the world without requiring specialized equipment. Unlike the Space Shuttle Orbiters, which required a significantly longer runway—generally between 12,000 feet to 15,000 feet—the Dream Chaser can land on a compatible runway that meets the minimum length and desired width

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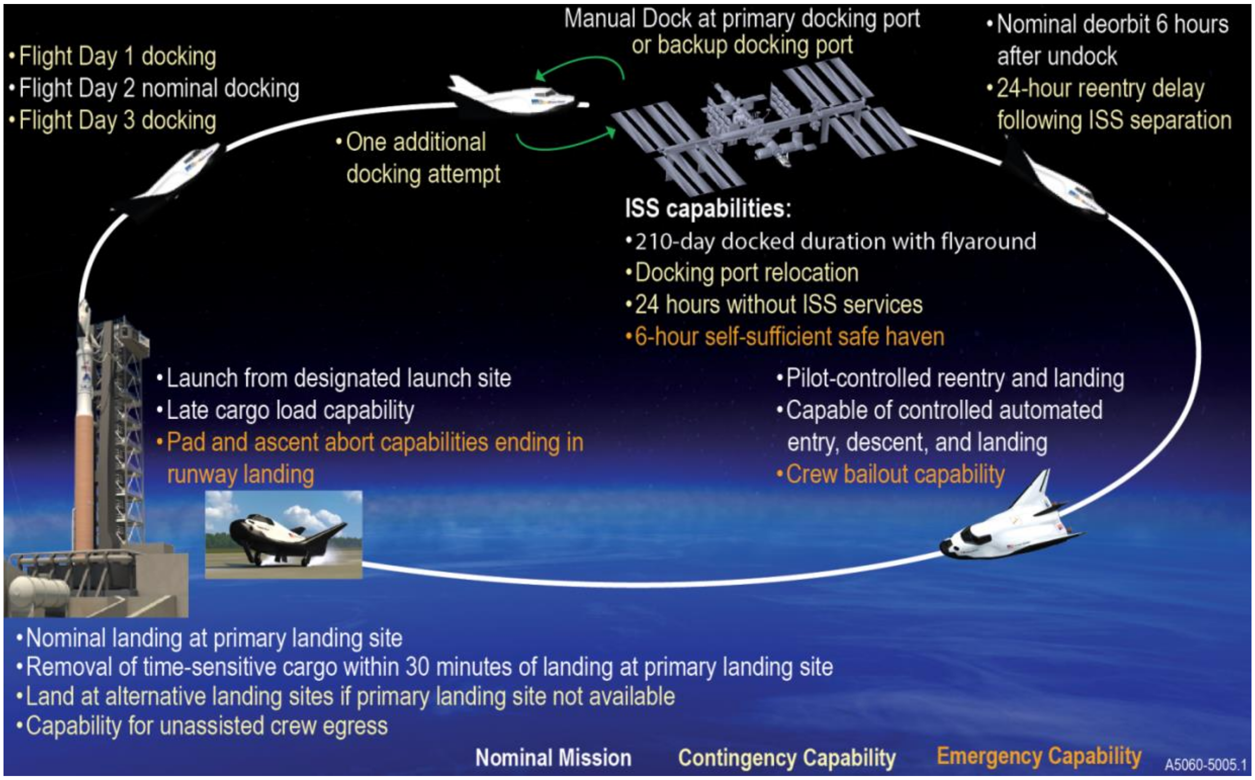

Figure 1. ISS Mission Concept of Operations. *SNC's Dream Chaser lifting body vehicle, launched aboard a United Launch Alliance (ULA) Atlas V launch vehicle, enables crew and/or cargo to land on a conventional runway.*

requirements, opening the door to broader landing locations and opportunities. Furthermore, by eliminating the need for hazardous materials the Dream Chaser will incur lower operational costs compared to other heritage or current development programs. Another advantage of the lifting body design of the Dream Chaser is the reduced acceleration reentries loads, which are on the order of 1.5g's or less. The gentle reentry helps preserve sensitive scientific payloads and provides a benign environment for crew return. The Dream Chaser will have frequent deorbit opportunities to landing sites in the United States and the ability to perform runway landings on every orbit during LEO missions. Thus, in case of a medical emergency, the Dream Chaser could land an injured crew member on a runway within a matter of hours.

II. Dream Chaser Landing Operations Nominal Concept of Operations

One of the many benefits of a reusable lifting body spacecraft is the ability to offer frequent landing opportunities. The reentry cross-range capability of 1,100 nmi for the Dream Chaser, shown in ***Figure 2***, exceeds Space Shuttle performance and allows the vehicle to maintain at least one runway landing opportunity every orbit.

Landing at a site within the contiguous United States (CONUS) is the first priority, unless otherwise directed by mission needs or emergency demands.

Landing site availability is not a constraint for the Dream Chaser. SNC has coordinated landing site usage with the Shuttle Landing Facility (SLF) in Florida, Vandenberg Air Force Base in California, and Houston's Ellington Airport in Texas, as illustrated in ***Figure 3***. SNC has also initiated discussions and assessments with multiple landing sites around the world. SNC's non-toxic propellants and operationally-friendly design offer immediate access to the spacecraft post-landing and also allows the Dream Chaser to be removed from the runway within minutes of landing, further reducing any opportunity for landing site conflicts for nominal (planned) landing sites as well as abort or emergency (unplanned) landing sites.

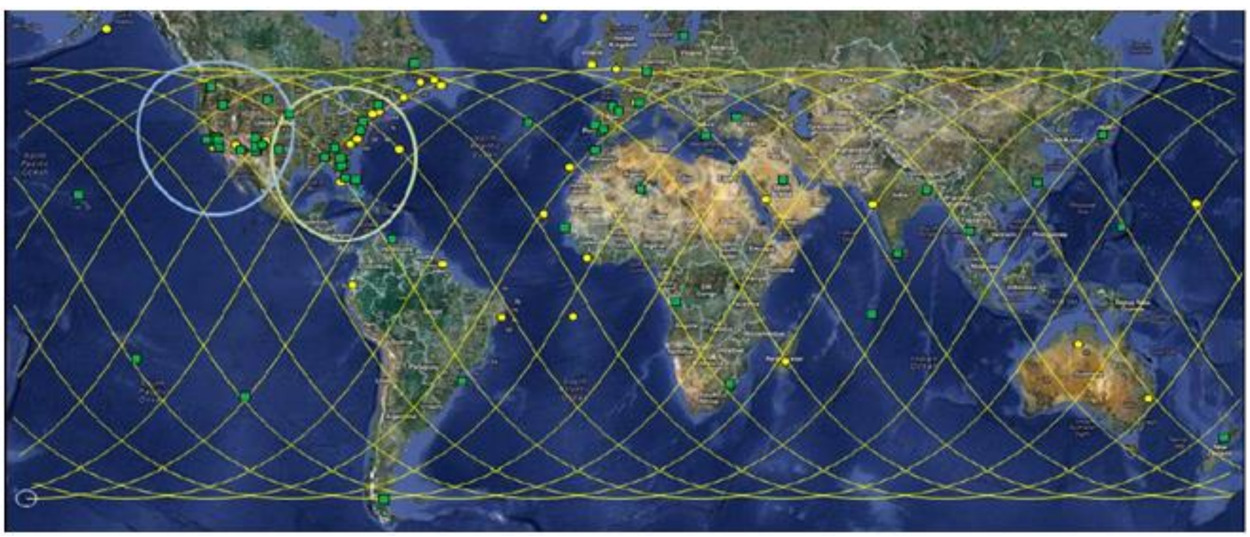

Figure 2. Dream Chaser Landing Opportunities. *Extensive cross-range capability of more than 1,100 nmi (distance illustrated by circles) allows for frequent landing opportunities on every CONUS overflight. The dots (yellow and green) indicate possible Dream Chaser landing and abort locations for an ISS mission, while the yellow dots indicate previous shuttle landing and abort locations.*

__Figure 3. Artist Concept of Dream Chaser Landing at Ellington Airfield, Houston, Texas.__ The Dream Chaser vehicle can land at any suitable runway that is at least 8,000 feet long.

A. Ascent Abort Concept of Operations

__Figure 4. Abort Sites Along Ascent Flight Path.__ The Dream Chaser lifting body with a cross range of 1,100 nmi is capable of landing at any of the identified runways during ascent, thus representing a significant benefit for crew, payload, and vehicle safety.

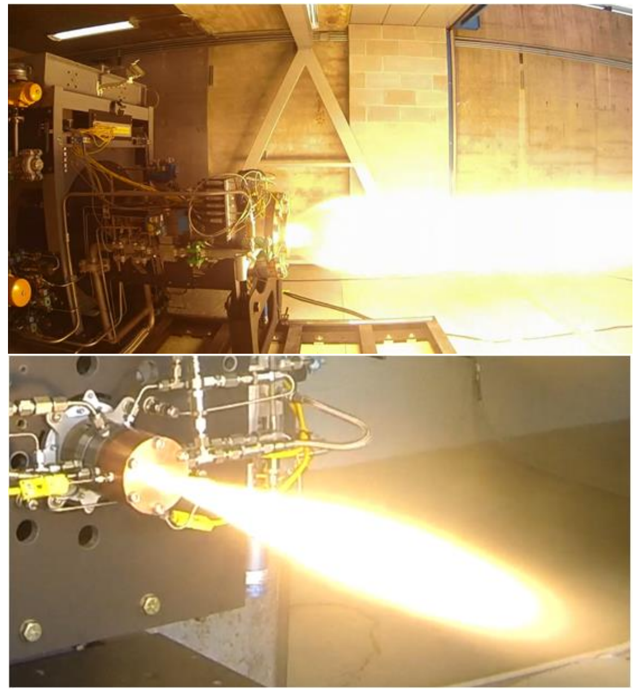

Figure 5. MPS and RCS Ground Test Firing: *The propellant for the Dream Chaser RCS and MPS are a non-toxic oxidizer (N2O) and fuels (propane) which enable immediate access to the vehicle upon landing.*

In an ascent abort, the Dream Chaser has continuous runway landing capability from the launch pad through the Atlas/Centaur launch vehicle trajectory. The Federal Aviation Administration (FAA) participates in regular collaborative dialogue with the Dream Chaser program and assists SNC in pre-coordinating emergency landings with identified landing sites. For ISS flights, SNC and the FAA will distribute Dream Chaser System operations documentation to all identified emergency landing sites, ensuring familiarity with the spacecraft in the event of an emergency landing. ***Figure 4*** shows a multitude of abort landing sites during ascent trajectory for ISS missions launched from Florida. For orbit aborts, the Dream Chaser runway availability is also frequent and accessible. Figure 4 also shows the numerous landing sites along the East coast of the U.S and trans-Atlantic landing sites in Europe. All of these landing sites for reentry and ascent abort are enabled by the subsystems that are incorporated into the Dream Chaser design.

B. Dream Chaser Vehicle Key Subsystems

The propulsion subsystem, autoland capability, Dream Chaser aerodynamics and Thermal Control System (TCS), presented here next, are key subsystems that enable the landing of the Dream Chaser space vehicle at a public-use airport.

Propulsion System. The *Main Propulsion System (MPS)*, also used for aborts, is composed of two liquid engines that rely on a non-toxic combination of Nitrous Oxide (N_2O) and propane (C_3H_8). The Reaction Control System (RCS) shares oxidizer and fuel with the primary propulsion system. Since the

Figure 6. SNC's Autoland Existing Proven Systems: *The existing autoland system—developed and fielded by SNC—was demonstrated in the X-47.*

Dream Chaser has significant delta-V margin on a nominal mission (greater than 50 percent) using a shared oxidizer and fuel for main propulsion and RCS saves hundreds of pounds while increasing mission flexibility. Additionally, by using shared oxidizer and fuel the Dream Chaser can provide fault tolerance for minimal additional weight by designing the RCS engines to also perform the deorbit burn and nominal ascent burns to ISS. ***Figure 5*** shows a ground test firing of both the MPS and RCS engines.

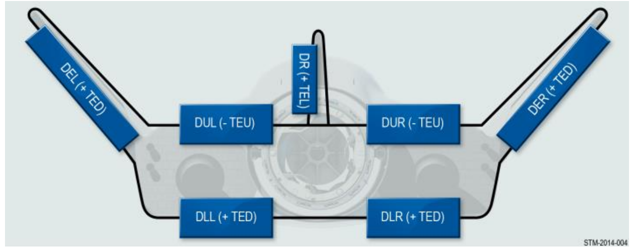

Figure 7. Dream Chaser Control Surfaces: *The Dream Chaser features seven control surfaces shown here from the rear of the airframe.*

Autoland Capability. The Dream Chaser is optionally-piloted, which means that while the vehicle is equipped with autoland capability, the primary method of landing a crewed mission is through crew control. Autoland capability enables completion of a nominal mission with deconditioned crew, cargo-only flights, and crewed abort trajectories. As expected, there are some limited abort scenarios where the accelerations are relatively high (~6 g's), although within crew limits. With such a dynamic, challenging event, the Dream Chaser program desired additional landing options besides crew-controlled descent. The components enabling the Dream Chaser autoland capability are typical of conventional aircraft and do not require any additional navigational aid (Navaid) equipment at the landing site. ***Figure 6*** shows SNC's existing capability of implementing autoland on existing uncrewed aircraft, such as the autoland system on X-47, for which the company was just awarded the prestigious Collier Trophy in 2014.

Aerodynamics. The Dream Chaser spacecraft shape is an intermediate between a true lifting body and winged vehicle in that its canted fins contribute about half of the net lift. There are seven control surfaces (CS) on the Dream Chaser, as shown in ***Figure 7***. Four body flaps (upper and lower, left and right) provide roll control when used as ailerons, supplementary pitch control when used as elevators, and drag modulation when used in unison as a speed brake. A full-motion vertical fin provides yaw control and reduces adverse yaw events due to body flap deflections. Two elevons (left and right) are installed at the trailing edge of the canted fins, providing the primary pitch control and supplementary yaw control. As shown in ***Figure 8***, the flight testing of the low-speed aerodynamic and in-ground-effect flight transition capability of the Dream Chaser during landing was successfully proven during the free flight test at Edwards Air Force Base in California, on October 26, 2013.

Thermal Control System. In conjunction with the primary propulsion system, the Thermal Control System (TCS) uses non-toxic fluids to enable quick access to the vehicle upon landing. The TCS system incorporates two N_2O boilers and a Phase Change Material (PCM) heat exchanger to control the temperature of the Dream Chaser vehicle while in the atmosphere. The PCM material is a wax-like material that can be reused by cooling the heat exchanger in space with the primary TCS system. The primary TCS fluid while in space is water (H_2O) through an evaporator. The combination of the N_2O and PCM enables the Dream Chaser vehicle to maintain temperature of all the systems, including the crew, during landing and after wheels-stop. This redundancy provides the option of removing the Dream Chaser off the runway before ground support equipment (GSE) is needed.

All of these key subsystems (propulsion, autoland, aerodynamic control, and TCS) enable post-landing procedures that are compatible with public-use airport operations and broader public and flight crew safety.

Figure 8. Dream Chaser on Final Approach: *The Dream Chaser space plane's first free flight and landing test was on Oct 26, 2013, at Edwards Air Force Base, California.*

C. Post-Landing Procedures

Figure 9 illustrates a proposed high-level post-landing task flow for the time a crewed vehicle is on a public-use runway. The Dream Chaser does not have the ability to taxi off the runway after landing like a conventional aircraft, which means landing at a public-use runway cannot be approached in the traditional sense. The flow presented in Figure 9 presents an efficient, new approach that is time-constrained in order to minimize time on a runway post-landing to allow public-use airports to resume normal operations as soon as possible with minimal impact.

To reduce time on the runway, the crew does not egress while on the runway, which represents a departure from Space Shuttle operating procedure. Rather, SNC's approach is to have the crew remain in the Dream Chaser until it is towed to a designated location off the runway where there are no time constraints to conduct all of the post-flight tasks. An alternative approach used to reduce time on the runway is the concept of utilizing parallel efforts. As ***Figure 10*** shows, after the vehicle is deemed safe to approach, three simultaneous operations begin. One team attaches the appropriate ground support equipment (GSE) while another prepares the vehicle for towing. During

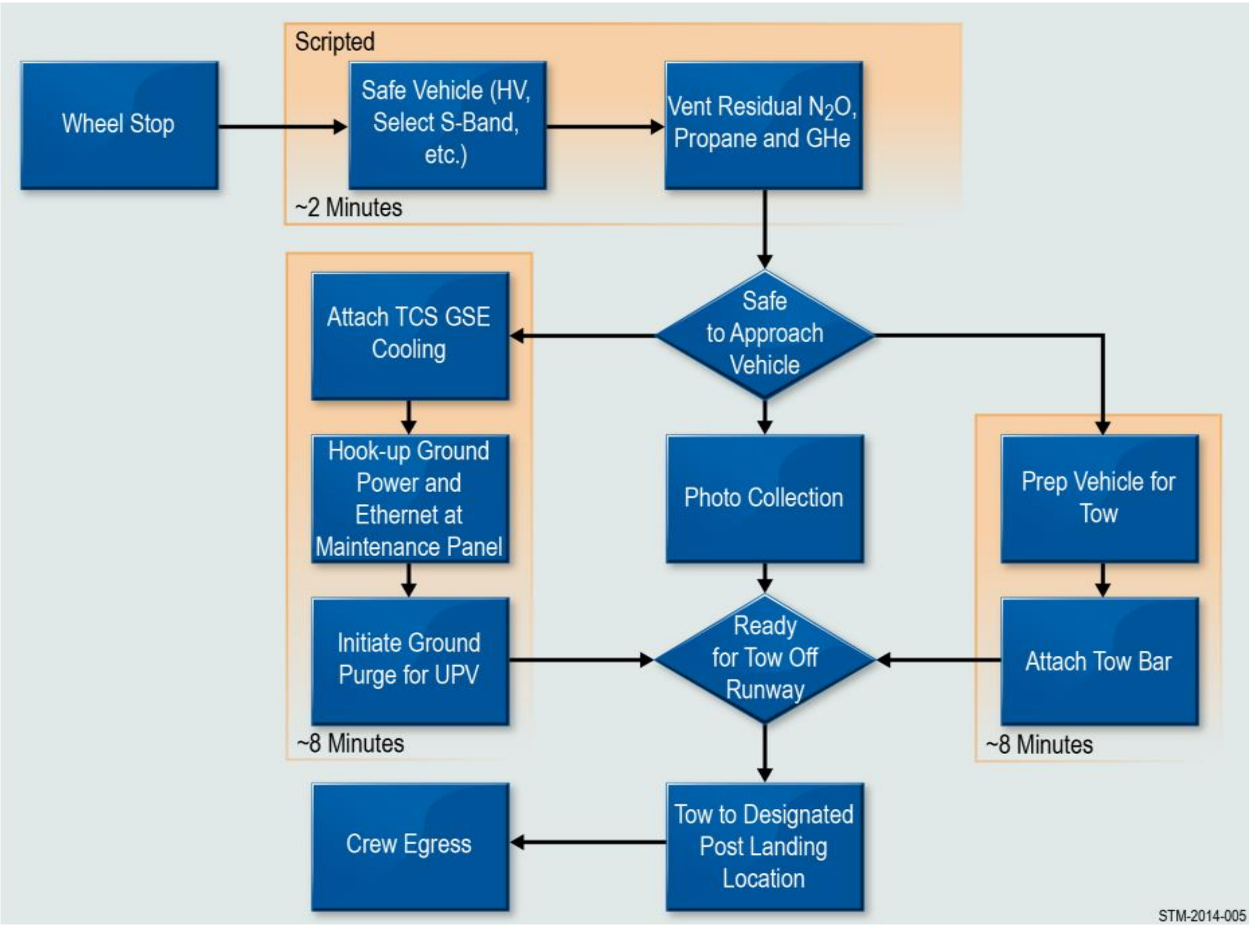

Figure 9. Public-Use Runway Post-Flight Runway Operations (Crewed): *Estimated duration is 10 minutes on an active runway.*

Figure 10. Dream Chaser Removal from Runway and Crew Egress. *The Dream Chaser's design allows unassisted crew egress at any landing site without the need for special equipment. This operation nominally occurs after the vehicle has been towed off the runway. The minimum equipment needed to quickly remove the vehicle from the runway is enabled by the low toxicity and low hazard levels of the Dream Chaser design, thus minimizing the impact on day-to-day operations at a public-use landing site.*

both of these efforts a crew member takes photos of pre-determined hardware to support post-landing evaluation and inspections. Figure 10 shows the post-flight operations sequence for a crewed flight to include the initial attachment of GSE to tow the Dream Chaser off an active runway to a secondary (off-runway) location for crew egress.

The GSE is designed to move with the vehicle while it is being towed off the runway. ***Figure 11*** shows a cooling cart capable of keeping the onboard crew comfortable until removal from the active runway. The Dream Chaser is a much less complex vehicle than other heritage systems and allows for minimal impact on day-to-day operations at a public-use landing site.

The uncrewed, cargo-only flights of Dream Chaser require a Flight Termination System (FTS). Traditionally, a FTS is ordnance-based, although the Dream Chaser development team is considering a few options that are not ordnance-based. For purposes of this case study, an ordnance solution is assumed as a worst case. The main difference between a crewed and uncrewed vehicle are the added steps to safe the FTS in order to allow the ground crew to safely work around the vehicle.

Figure 11. Dream Chaser Attachment to Ground Support Equipment. *The Dream Chaser design allows for standard ground support equipment (tow bar and cooling cart) to interface with the vehicle after removal from an active runway.*

Figure 12 shows an initial set of scripts used to safe both the FTS and vehicle while venting any residual commodities. After verification that these tasks are completed, a two-person ground crew approaches the vehicle and places safing pins in the Safe and Arm devices for the FTS. From there, the vehicle is considered safe to work around and other ground crew personnel begin parallel efforts. Much like with a crewed vehicle, one crew connects GSE and another prepares for towing while photos are taken. Once all parallel efforts are completed, the vehicle is towed to a post-landing processing location. Even with these additional steps for safing the FTS for uncrewed missions, the necessary steps can be completed in a timely fashion allowing the public-use airport to have minimal impacts or delays to other users.

III. Process of Obtaining Authorization to Operate at a Public-Use Airport

One of the unique features of the Dream Chaser system is its ability to land horizontally on a compatible runway. While there are a number of government-owned landing sites, such as the Shuttle Landing Facility (SLF) at NASA's Kennedy Space Center in Florida, the ultimate goal of Dream Chaser is to provide commercial services to a broader commercial market. With this goal in mind, it will be important to develop a network of potential landing sites around the world for both nominal and contingency (emergency) situations. When considering the reentry and landing of an orbital spacecraft at a public-use airport, there are number of important considerations that must be

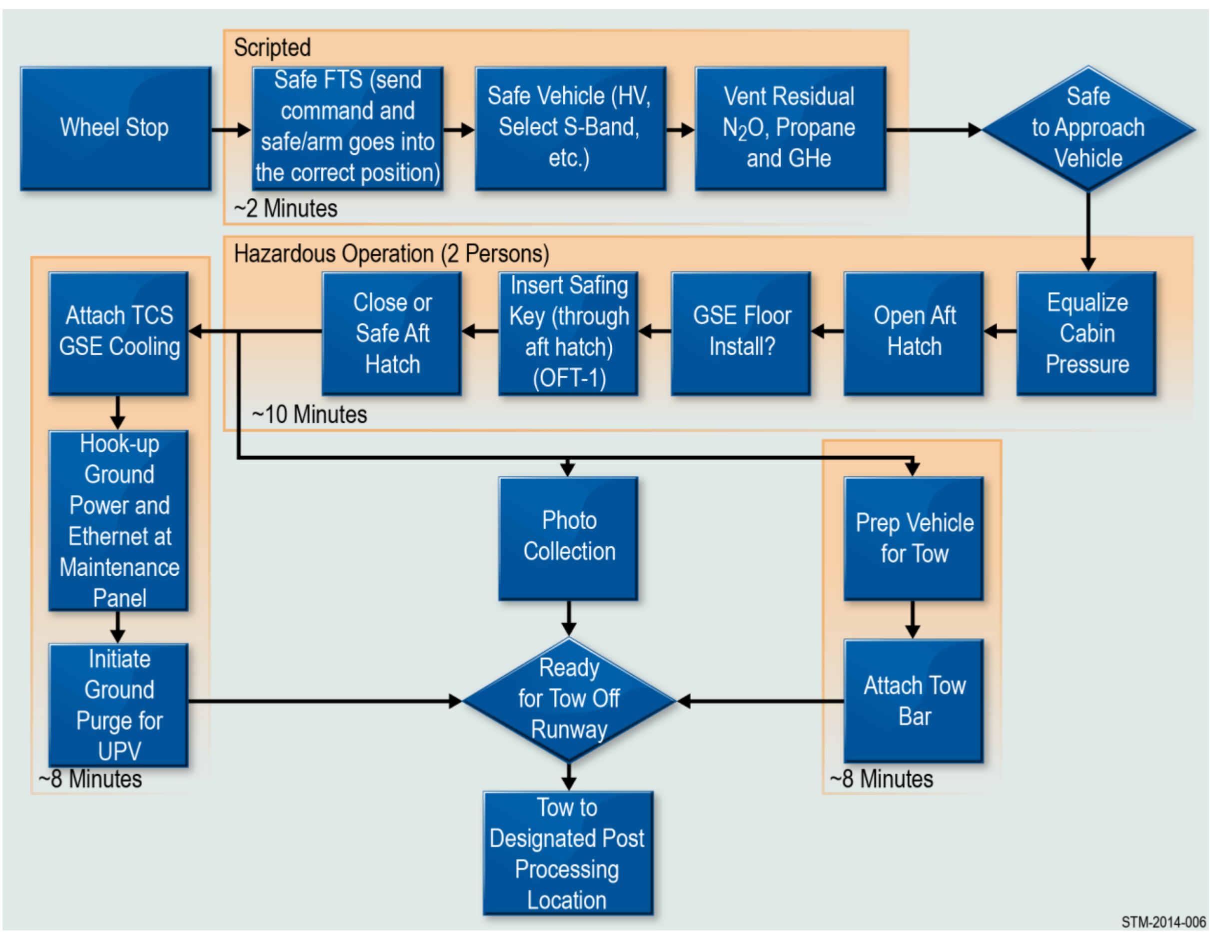

Figure 12. Public-Use Runway Post-Flight Operations (Uncrewed). *Estimated duration is 20 minutes on an active runway.*

addressed, including airport facilities, airport operations, airspace coordination, and licensing.

A. Airport Facilities

The Dream Chaser has specific infrastructure and operational requirements that must be supported by each of its landing sites, including those at public-use airports. The specific airport requirements include: compatible runway (>8,000 feet/2,400 meters long with concrete surface preferred and a minimum 150ft width), appropriate separation distances after removal from active runway, security of the temporary parking, and processing hangar and ground support equipment.

1. Compatible Runway

The Dream Chaser requires a runway with a minimum length of 8,000 feet (2,400 meters) for landing. In addition, because the Dream Chaser front landing gear uses a skid instead of a rolling nose wheel, the ideal runway would be constructed of concrete instead of asphalt. An asphalt runway landing may require the modification to the Dream Chaser nose skid material. Tests of the landing skid have demonstrated that concrete runways are durable enough to withstand the vehicle's existing skid material without causing unusual wear and degradation to the runway. During the flight test campaign at Edwards Air Force Base (as shown in ***Figure 13***) the Dream Chaser nose skid was towed more than 20 miles in numerous ground taxi tow tests. During the campaign, the nose landing skid imparted no damage to the runway, striping, or runway centerline lighting. Additionally, no damage was done to the runway when the test configuration left main landing gear did not properly deploy during an atmospheric flight test. The ground tow and flight testing proved that the skid material is compatible with existing concrete runways.

In addition to length, width, and composition of the runway, another critical consideration is runway availability. Since the Dream Chaser does not have an onboard method for taxiing, it will continue to occupy the runway until it is properly safed and towed to a designated location at the airport. For some high-volume or single-runway airports, it may be difficult to suspend aircraft use of a runway during this period of time. SNC is working on reducing the timeline needed to safe the vehicle and tow Dream Chaser off the active runway. As described above, the current estimate is between 10 and 20 minutes, post-landing.

2. Appropriate Ground Separation Distances

The Dream Chaser is designed to use non-toxic propellants which eliminate the need for specialized propellant off-loading systems at the landing site and in post-landing processing and hangar storage facilities. The current concept of operations is to vent residual oxidizer prior to landing, thereby reducing potential explosive hazards at a landing site. In the event that oxidizer/fuel venting fails, adequate separation distance may need to be provided on the ground to ensure public safety.

3. Ground Support Equipment

The Dream Chaser is designed to require minimal Ground Support Equipment (GSE). Most of the GSE that is required can be temporarily deployed to the landing site ahead of a scheduled arrival. In some instances, locally available GSE such as an aircraft tug, tow bars, and cooling carts, can be used. Existing tugs and tow bars will be pre-verified as compatible with the Dream Chaser skid nose gear to facilitate quick removal of the Dream Chaser off the active runway within 10 to 20 minutes**.**

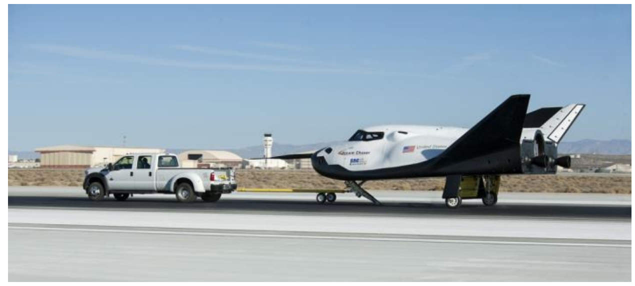

Figure 13. Dream Chaser Ground Tow Testing at Edwards Air Force Base. *The Dream Chaser was tow-tested for more than 20 miles with no damage to the runways at Edwards Air Force Base, proving the compatibility of the skid with an existing runway.*

B. Airspace Coordination

The Dream Chaser descends from orbit as a glider, with both a very high velocity and a high sink rate. This renders it incompatible with typical aircraft operations and requires special handling from Air Traffic Control facilities. All commercial aircraft operating at altitudes between 18,000 feet mean sea level (msl) (FL180) and 60,000 feet msl (FL600) are required to operate on flight plans generally under Instrument Flight Rules (IFR) requirements and must be in contact with FAA air traffic controllers. Below 18,000 feet msl (FL180), many aircraft are not on flight plans with a mix of IFR and Visual Flight Rules (VFR) operations and, depending on the geographic area, may not be in contact with air traffic controllers.

These combined considerations make it essential that the Dream Chaser descent be planned in coordination with air traffic control. Specific blocks of airspace must first be identified before planning an airport descent and approach. Letters of Agreement among the various controlling agencies establish the procedures for reserving airspace and ensuring appropriate traffic management. With a pre-authorized reservation in place, commercial air traffic can be routed around the intended flight corridor until the Dream Chaser vehicle lands. ***Figure 14*** illustrates the direct approach path to Ellington Airport.

C. Compatibility with Existing Airport Operations

Each airport has a unique set of operational conditions ranging from low volume, single-runway general aviation (GA) airports all the way up to high volume, multiple-runway large hub airports. The type of airport certification, the existing airport capacity, the sensitivity of the local population, the geo-political climate, and the acceptance of the airport management are all important considerations when assessing the viability of a specific airport to support reentry and landing operations of an orbital spacecraft.

While federal regulations prohibit most airports from "discriminating" against users – that is, favoring one type of aircraft over another –space vehicles are not currently defined as aircraft. For that reason, airports must ensure that spacecraft operations do not adversely impact aviation operations. Runway loiter times or delays, possibly experienced during Dream Chaser safing procedures and tug operations, may represent a challenge for some aviation operations. For that reason alone, some airports may be undesirable or - in the extreme - incompatible with Dream Chaser operations. These issues must be carefully considered.

Another area of interest stems from the planned ability to land the Dream Chaser autonomously as an uncrewed (unpiloted) vehicle. A piloted return would meet the requirements of operating into an airport under current FAA policy and regulation. However, an unpiloted landing could be construed as an operation equivalent to an unmanned aerial vehicle, for which the FAA is currently evolving its policies.

D. Licensing

The FAA Office of Commercial Space Transportation (FAA/AST) has established regulations to govern the licensing of the return of spacecraft such as the Dream Chaser. Presently two parts of regulation exist for the licensing of reentry, Part 431 and Part 435. The Dream Chaser will be subject to 14 CFR Part 431–Launch and Reentry of a Reusable Launch Vehicle (RLV).

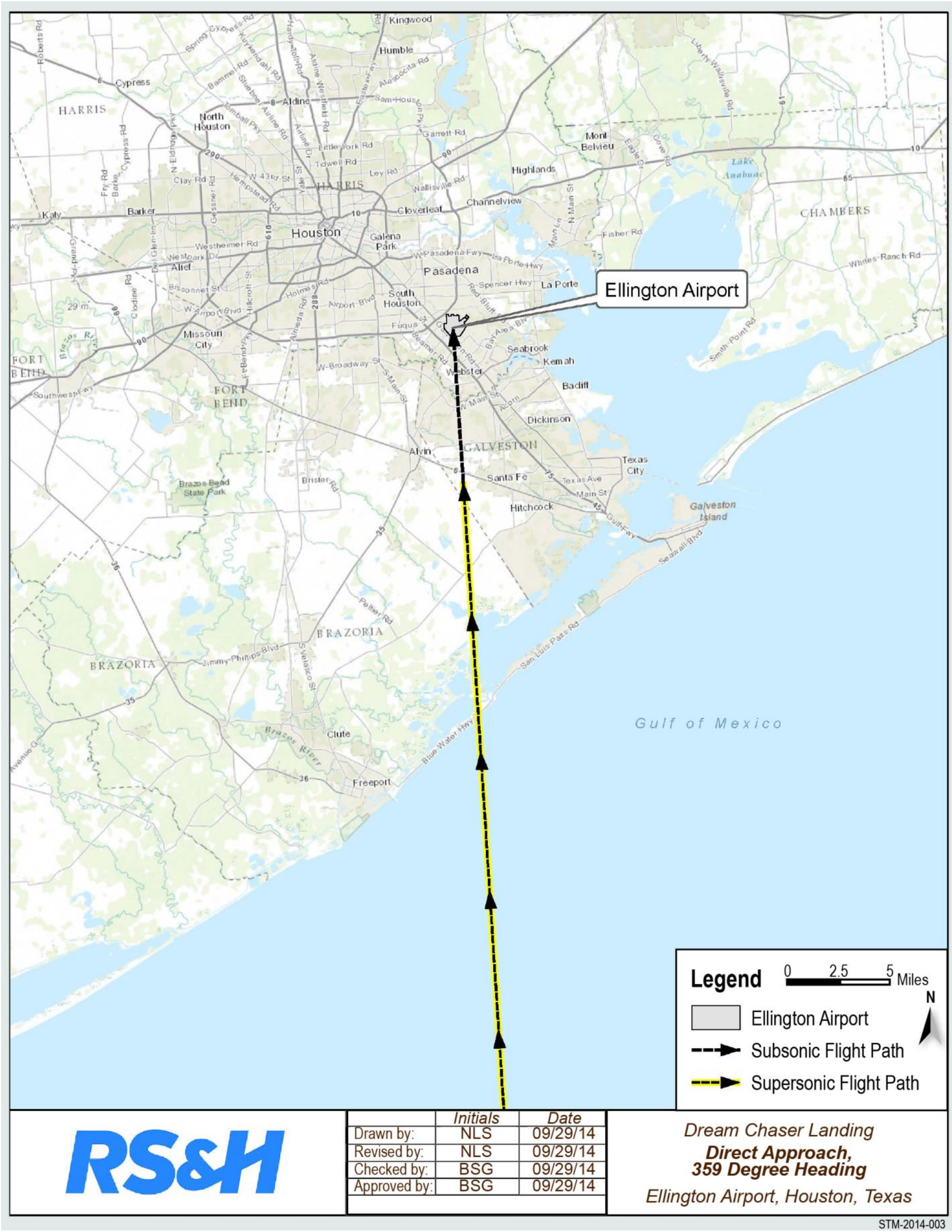

Figure 14. The Direct Approach Path for the Dream Chaser to Ellington Airport. *A direct approach allows Dream Chaser to maneuver in the Gulf of Mexico to align with Runway 35L with no supersonic flight maneuvers over land.*

The regulations require a number of reviews be completed to demonstrate safety and compatibility with the reentry site. These reviews include a policy review, a safety review, a payload reentry review, and an environmental review. As part of the post-licensing requirements, agreements with FAA and the U.S. Coast Guard are required to develop procedures for notifying airmen and mariners, as appropriate. In addition, placeholder regulations in 14 CFR Part 433–License to Operate a Reentry Site currently exists although minimal regulations are present. It is expected that at a future date additional regulations will be added that are unique to reentry sites.

1. Public Safety

A major consideration for landing a space vehicle on any runway is public safety. The Federal Ranges, NASA, and the FAA quantify this in terms of an Expected Casualty (E_c) calculation. The E_c calculation takes into account vehicle properties such as debris breakup predictions, failure modes, and trajectory to calculate an expected public risk of either serious injury or fatality due to an accident. Currently the FAA uses a limit of not to exceed 0.00003 casualties ($30x10^{-6}$) which defines the level to which the public is exposed to hazards from the flight. This value is more restrictive than both the Federal Ranges and NASA, which have a $100x10^{-6}$ E_c limit. In a recent Notice of Proposed Rule Making (NPRM), the FAA has recommended updating their E_c limit for both launch and reentry operations to $1x10^{-4}$ in order to be consistent with the other organizations. They will also be proposing that the calculations be split for both launch and reentry to accommodate more vehicle and mission types. In the case of landing on a public-use runway, an E_c calculation will be required to be presented to the FAA for evaluation. The FAA has provided an advisory circular on E_c calculations that details the approach a public-use company should follow in order to generate a conservative estimate of expected casualty. The onus is on the Dream Chaser program to supply the calculation to a level of detail that meets the approval of the FAA.

In general, overflight of higher population densities will result in a larger E_c, although this can be managed and optimized with flight corridors and profiles. When evaluating landing sites, the Dream Chaser team will work closely with the FAA in order to designate trajectory corridors where risk within the acceptable limits can be achieved. It is the goal of Dream Chaser to be able to support regular public-use access to and from space, with public safety always in mind, by working closely with the FAA.

2. Noise Considerations

The Dream Chaser returns for landing with an airspeed in excess of Mach 5 above 100,000 ft, and significantly slows on the flight profile with a landing speed of less than 200 knots. Supersonic flight is generally prohibited over land in the continental United States, although FAA does grant waivers. In order to determine the acceptability of the proposed landing flight corridor, an analysis must be made of the potential for sonic booms to be heard on the ground.

Currently FAA does not have specific guidelines for the level of sonic boom that is acceptable during the approach, and approval depends on issues such as population density and environmental sensitivity of the overflight area. This represents an issue FAA is currently studying and the requirements may change in the coming years. Based on initial analyses, the maximum overpressure of the sonic boom generated by the Dream Chaser during landing is expected to be less than the maximum overpressures generated during a Space Shuttle landing.

E. Special Considerations for Licensed Spaceports

A number of existing and proposed commercial licensed spaceports exist which may be compatible with the proposed reentry and landing operations of the Dream Chaser. The proposed Houston Spaceport at Ellington Airport is an example of one such spaceport that is currently coordinating with SNC and the FAA to host such landings. In some instances existing spaceports may have an advantage over non-spaceports (including public-use airports) when supporting Dream Chaser landings, however not every licensed spaceport is compatible.

Some of the benefits of hosting landings at a licensed spaceport are that coordination with the appropriate agencies and the public can be streamlined, as prior coordination was completed during the spaceport licensing process. Similarly, because licensed spaceports have previously completed both environmental and airspace coordination, the appropriate stakeholders are already familiar with proposed operations of space vehicles. In many cases approved flight corridors or arrival routes are identified for approved spaceports that could potentially be utilized by Dream Chaser.

Some licensed and proposed spaceports have asphalt runways that may require some modification to the landing skid on the Dream Chaser. This is currently being assessed. Also, while appropriate National Environmental Policy Act (NEPA) documentation was completed as part of the spaceport licensing process, additional and future work for the environmental analyses may be required to support landings of the Dream Chaser. In particular, a sonic boom analysis would need to be completed to understand the region of influence for both the local population and environmentally sensitive areas.

IV. Future Work

The need for future work in the areas of environmental analyses due to sonic boom and trajectory shaping will need to be completed to gain final NEPA approval for Dream Chaser landing at spaceport and/or public use airports, such as Ellington Airport. Through the use of sonic boom analytical software such as PCBoom, a standardized method can be used to understand the impact and develop an optimal flight path.

Additionally, E_c analysis will provide the assurances for public safety by establishing that the risk to the public is acceptable for the entry of the spacecraft into the atmosphere and landing at a public-use airport or commercial spaceport. E_c analysis to date has been calculated by unique methods for each of the established orbital reentry landing sites (Cape Canaveral and Vandenberg Air Force Base). It is a goal of SNC, as a commercial spacecraft operator, to establish consistent methods and subsequent results that are recognized by each of the different government agencies. This will allow for an accurate, manageable and economical procedure to define the E_c needed to ensure public safety.

The combination of future work on sonic boom and E_c analyses is paramount to establish the trajectory that is acceptable to NEPA and FAA for public safety. The next consideration will be the integration of these acceptable trajectories into the established National Airspace System (NAS). This integration of a spacecraft into the NAS is one of the less predictable considerations which will need to be resolved in order to obtain authorization to land a spacecraft on a public-use airport or commercial spaceport.

The Dream Chaser continues to work to further refine the post-landing process. The design is being developed to accommodate standardized ground support equipment that support conventional aircraft to better integrate the Dream Chaser at public-use airfields. Similarly, processes are being developed to comply with the same OSHA requirements that dictate working with aircraft. As specific sites are identified so too are activities that may streamline vehicle operations, for example high speed off-ramps to taxiways may alleviate the need for towing the vehicle off the runway. Overall, more work is needed to fully understand the constraints public-use airports face to support a Dream Chaser landing, and to develop processes to accommodate Dream Chaser flights accordingly.

V. Summary

SNC's Space Systems is developing the Dream Chaser reusable, optionally-piloted, lifting body space vehicle for a variety of low Earth orbit missions. The Dream Chaser is a lifting body vehicle that lands on a runway similar to the Space Shuttle, but unlike the Shuttle, the Dream Chaser only requires 8,000 feet/2,400 meters of runway for landing. The design of the subsystems for the Dream Chaser space vehicle were all developed with the goal to minimize the need for specialized ground equipment and to enable early access to the crew and cargo after rollout and wheels-stop. The subsystem design incorporated in the non-toxic propulsion and thermal control systems enables the immediate access to the vehicle along with minimizing the support equipment needed to remove the vehicle from the active runway or taxiway. In addition to the use of non-toxic consumables, Dream Chaser benefits include its aerodynamic control and the options of both crewed and autoland capability that enable its landing at public-use airports.

Procedures and authorizations are needed to complete the integration of the Dream Chaser with a public-use airport. The analysis of public safety through E_c calculation, sonic boom, and trajectory shaping to minimize environmental impact are just part of the work needed to implement a spacecraft into a public-use airport. Additional forward work includes gaining authorization for the Dream Chaser to land at a public-use airport, the integration of the Dream Chaser into the air traffic system and further refinement for safing and transportation procedures for the spacecraft post-landing. An alternative option to using public-use airports is the emergence of commercial spaceports, which may already have approved flight path corridors.

These are just a few of the key current issues in landing a crewed spacecraft into public-use airways and airports. The emerging use of uncrewed (unpiloted) vehicles is a developing issue that the FAA is just now starting to address and changing processes for gaining access for uncrewed/autonomous spacecraft will most certainly mature. Similar to piloted vehicle integration into existing airways and airports, processes and procedures needed to land an unpiloted spacecraft into a public-use and commercial spaceport are also evolving.

This paper summarizes the current issues and status of developing procedures and processes needed to gain access to public-use and commercial spaceports. The authors of this paper welcome and encourage further dialog with appropriate agencies and operators of runway-landing spacecraft to develop a consistent and established procedure to gain access to public-use airports and airways.

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