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Balloon Mishap in the Outback

Nuclear Compton Telescope Balloon Mishap

Alice Springs Balloon Launch Station, Australia, April 29, 2010: During the launch attempt of the Nuclear Compton Telescope (NCT) scientific balloon, the payload broke free of the launch vehicle and was dragged through an airport fence and into a group of spectators, damaging two private vehicles before coming to rest. While spectators evaded the balloon payload and avoided injury, the payload suffered extensive damage. Although a routine launch attempt had ended in a high-visibility mishap, the Program and Safety personnel would learn valuable lessons for future balloon launch operations.

PROXIMATE CAUSE

- Payload separated from launch vehicle
- Released payload was dragged downwind by the balloon
- Public spectators were in downwind payload path

UNDERLYING ISSUES

- Safety oversight
- Hazard area definition and barriers
- Hardware design

AFTERMATH

- Development of a more stringent launch safety area to protect the safety of the public and also allows for balloon launch vehicle maneuverability
- Revision of the safety procedures used to conduct balloon launches
- Institution of NASA independant ground and flight safety roles to ensure that balloon launches are conducted safely
- Redesign of the launch head mechanism, which failed during the Australia aborted launch
- Improvement of plans to better respond to mishaps and close calls with respect to balloon launch operations

Background

The History of Scientific Ballooning

Ballooning has provided invaluable scientific discoveries in the field of space and Earth science. Since the 1970s, the National Scientific Balloon Facility (NSBF)—now the Columbia Scientific Balloon Facility (CSBF)—has launched science missions for NASA from the Australian outback. Since 1983, NASA's Balloon Program has been managed by the Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF). The Balloon Program currently conducts approximately 16 to 18 flights each year.

The Balloon Launch Process

High altitude balloons are made of very thin polyethylene film; therefore, the balloon material is laid out on the ground over a protective cloth to avoid tearing. A small portion of the balloon (the "bubble") is filled with helium and it is restrained by a spool (Figure1). The scientific payload is connected to the balloon by steel cable and an unpacked parachute. Prior to launch, the payload is suspended from the launch vehicle (modified mobile crane) using a steel plate attached to a releasable pin.

The CSBF launch team conducts launches using a dynamic launch process per NASA ground and flight safety plans. To launch the balloon, the bubble is released from the spool and the whole balloon flight train—bubble, parachute, and steel cables—achieves vertical alignment over the payload, still attached to the launch vehicle.

Once vertical over the launch vehicle, the balloon is launched by using a pin-release

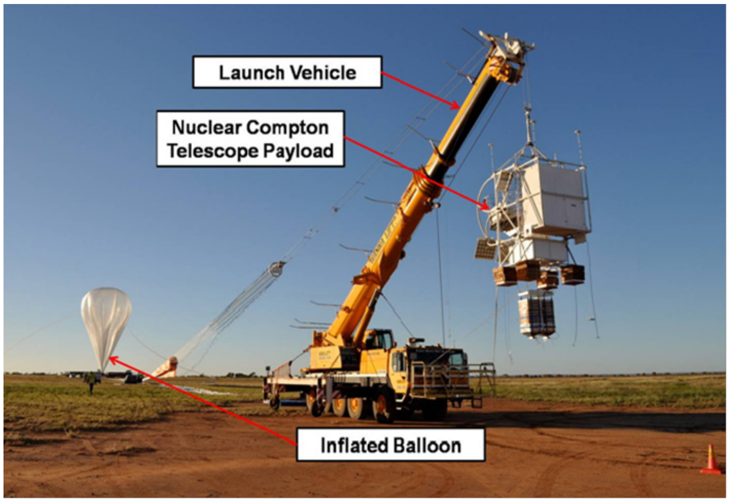

Figure 1: Launch configuration for the NCT during the day of the launch, preparing for release of balloon. Note the inflated balloon bubble.

mechanism on the end of the crane boom. The balloon fills out as the helium expands in the upper atmosphere and float altitude.

Mobile Launch Operations

The NASA and CSBF balloon launching practice is highly mobile and flights can be conducted almost anywhere in the world. Potential launch weather constraints make this capability invaluable. Launches from mid-latitude sites (e.g., Australia) afford greater sky coverage in addition to a greater observation range for gamma-ray astrophysics payloads (e.g., the Nuclear Compton Telescope). For Australian operations, the crane vehicle is locally rented and then configured into the launch vehicle.

Specialized equipment, such as the protective ground cloth, is shipped in and deployed with the locally obtained equipment. The University of New South Wales (UNSW) manages the Alice Springs Balloon Launch Station at the Alice Springs airport for CSBF under the direction of an UNSW Site Director (SD).

The Nuclear Compton Telescope

The NCT, built by the University of California Berkeley, was designed to further advance understanding of gamma-ray measurement in preparation for the Advanced Compton Telescope Satellite. First flown on June 1, 2005, the NCT gathered useful data and was successfully flown on multiple occasions.

Conditions

Launch Day

In the early hours of April 29, 2010, the launch team began to monitor the atmospheric conditions including wind direction and velocity in preparation for the launch later that day. Pilot balloons (small weather or sounding balloons) were released up until launch, beginning at 2:18 a.m. Australian Central Time (ACT). A tethered balloon was also set up on the launch vehicle to indicate wind up to an altitude of 1,000 ft. The wind speed and direction at this altitude determine any maneuvering of the launch vehicle below the balloon as the balloon train is released.

The ground crew decided that conditions were acceptable for launch. Helium inflation commenced at 6:43 a.m. and was completed at 7:50 a.m. A final pilot balloon, released 10 minutes prior to launch, indicated a slight wind increase from the south. Regional air traffic control requested a 10-minute hold to clear air traffic, and then launch proceeded.

Spectators on the Fence

After the balloon bubble was inflated, but before spool release, the CSBF Launch Director noticed that some spectators had gathered downwind of the balloon's projected payload flight path (Figure 2). He requested that these spectators be moved. The UNSW SD responded and put out the request over the radio. An off-duty CSBF crew member, who was among the spectators, and the deputy UNSW SD heard the request.

The crew member, located south of the eventual flight path, moved spectators to the north while the deputy SD, located north of the eventual flight path, moved spectators south. This confusion and the final wind shift placed many spectators directly in the launch line.

Some spectators parked their vehicles off road while others stood against the airport fence to watch and photograph the launch.

Pre-launch flight safety assessments had only considered the ascent and over-flight phases, not the launch phase. The ground safety plan defined a hazard zone for balloon layout and launch, but it was unclear whether the hazard zone was fixed or moving with the launch vehicle.

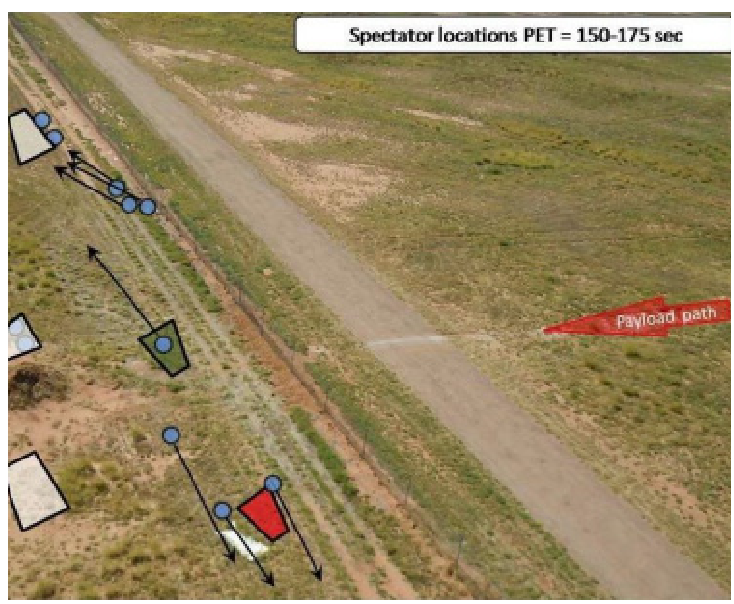

Figure 2: Spectator locations (blue) in comparison with the payload path. Source: Mishap Investigation Board Report

The Mishap

Catching Up

At 8:05 a.m., the launch spool was released, allowing the balloon flight train to achieve vertical orientation. The balloon rose quickly and, because of the crosswind, drifted slightly to the north. Ten seconds after spool release, the Launch Director moved the launch vehicle in a northwest arc to achieve a better alignment with the balloon prior to launch. After moving in this arc for 35 seconds, the Launch Director realized that the balloon was slightly ahead of the launch vehicle. The launch vehicle made a 90-degree left turn to realign itself with the projected flight path. Shortly afterward, the vehicle briefly lost traction and became temporarily stuck in the soft ground.

After the launch vehicle regained traction and repositioned, the Launch Director attempted to launch the balloon, but after pulling the lanyard to release the pin (Figure 3), the balloon failed to release.

The payload began to swing violently. The Launch Director attempted again to release the pin but was unable to do so. The balloon continued to travel downwind, and the Launch Director moved the launch vehicle again to catch up with the balloon for another launch attempt. Approximately 15 seconds later, the launch vehicle was forced to stop at the perimeter fence where the spectators were located.

Abort

Recognizing the unsafe proximity to the spectators and that the launch vehicle could not proceed any further, the Launch Director directed the launch vehicle to back away from the fence. Conditions made it unsafe to abort; by releasing the balloon without the payload, there was a possibility that the balloon train could fall on the spectators. The launch vehicle backed away from the fence, again losing traction in the soft ground. Intending to abort, the Launch Director attempted a left turn to move away from the spectators. The restraint cables failed under excessive side loading and the payload was inadvertently released (Figure 4).

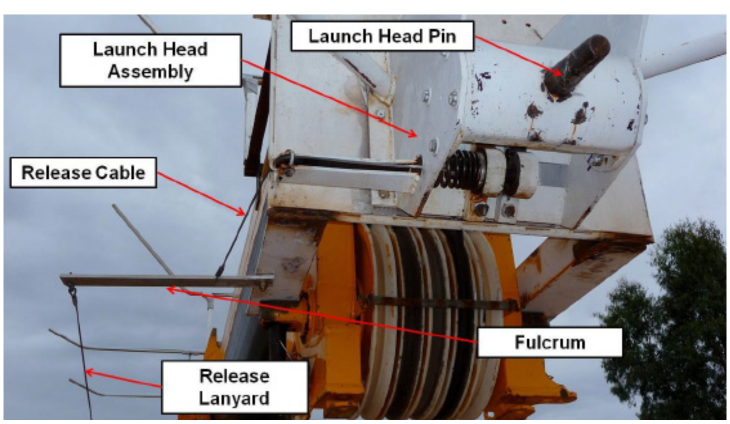

Figure 3: The launch head assembly showing release lanyard and pin. The release lanyard must be activated manually.

Figure 4: NCT payload crash site; the NCT sustained major damage.

The payload was dragged along the ground through the fence and collided with spectator vehicles. Fortunately, the spectators evaded the incoming payload without injury.

Proximate Causes and Underlying Issues

Safety Oversight

A NASA Mishap Investigation Board (MIB) was formed for this incident. It found multiple causes that led to the mishap. The MIB identified an inadequate flow-down of Agency requirements to protect the public, in addition to a marked absence of an individual trained to ensure public safety.

Although a ground safety plan existed, it did not cover all phases of flight (i.e., launch, float, termination, and recovery) and the hazards relevant to each phase. The MIB also found that launch crew training did not address failed launch attempts or off-nominal flight behavior. Furthermore, no standardized launch procedure existed at the Alice Springs launch site.

Hazard Area Definition and Barriers

The MIB noted that there was no barrier, such as a roadblock or designated spectator viewing area, to keep the general public out of danger throughout the launch process.

Hardware Design

The MIB recognized that the Program was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver, or that the payload release system needed to be analyzed for launch limitations.

Aftermath

After the Australian mishap, the Balloon Program responded by conducting an extensive evaluation of launch safety processes and procedures. To prepare for a return to flight, GSFC developed a corrective action plan to address the recommendations from the mishap review which led to

- Development of a more stringent launch safety area in order to protect the safety of the public that also accounts for balloon launch vehicle maneuverability
- Revision of the safety procedures used to conduct balloon launches
- Institution of NASA independent ground and flight safety roles to ensure that balloon launches are conducted safely
- Redesign of the launch head mechanism, which failed during the Australia aborted launch
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After implementing the recommendations and conducting Return to Flight reviews for each launch site, the GSFC Center Director granted approval for the Balloon Program to resume operations in December 2010. Since then, balloon campaigns have been safely and successfully conducted in Antarctica, Australia, Sweden, and New Mexico using the revised NASA safety processes.

For Future NASA Missions

For over 30 years, the Balloon Program has been dedicated to providing the highest quality flight support to the NASA science community. This support has been marked by a safe and efficient, non-bureaucratic culture, that pushes the boundaries to improve balloon capabilities for the science community.

In an Agency focused on high-priority flight missions with critical system reliability requirements, the Suborbital Program plays a vital role in enabling low-cost, cutting edge scientific and technological investigations with an acceptable level of mission success. Despite setting lower mission assurance requirements for suborbital missions, NASA does not accept a lower standard of safety.

In the mid-1980s, NASA opened the contract for operations at NSBF/CSBF to competition. Through commercializing and privatizing its contract activities, the NASA balloon contract eventually became performance-based. Over time, this drove clean interfaces between NASA and CSBF roles, such that the complete end-to-end launch and safety operations would be conducted by CSBF with minimal oversight by NASA, as is appropriate for a performance-based contract. This contract approach, combined with very remote balloon campaign locations, led to limited NASA safety insight and participation during launch operations.

In response to the mishap, the Balloon Program and NASA Safety and Mission Assurance personnel worked to fix the safety deficiencies exposed by the mishap, while trying to preserve the responsive nature inherent in the Program. This required an extensive reevaluation of ground and flight safety procedures, risk analyses, safety roles at launches, and personnel training.

Today, NASA conducts formal safety analyses for all balloon operation hazards, covering all phases of the mission from set-up through recovery. Analyses are then used in campaign-specific Flight Safety Plans (FSP). Further, the Program prepares Mishap Response Contingency Plans that include launch site and mission specific details reviewed during table-top exercises prior to launch. NASA Safety and Balloon Program personnel are in attendance at every launch, and NASA Safety personnel independently assure Balloon Program compliance with NASA safety requirements.

Since the NCT mishap, there have been four major multi-flight campaigns using these new procedures. The result has been increased understanding and appreciation on the part of all participants as to the important roles each organization has for safety. Looking to the future, there will be an ever more critical need for NASA to continue to safely conduct suborbital science and technology investigations, providing important hands-on experience for science, technology, engineering and mathematics [STEM] undergraduate and graduate students. Through the lessons learned from the Australian mishap, the Balloon Program is a safer and stronger program in implementing NASA's mission.

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SYSTEM FAILURE CASE STUDY

NSC

NASA SAFETY CENTER

Responsible NASA Official: Steve Lilley steve.k.lilley@nasa.gov

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