



Re-entry and Risk Assessment for the Tropical Rainfall Measuring Mission (TRMM)

NASA Orbital Debris Program Office

Updated on 4 June 2015



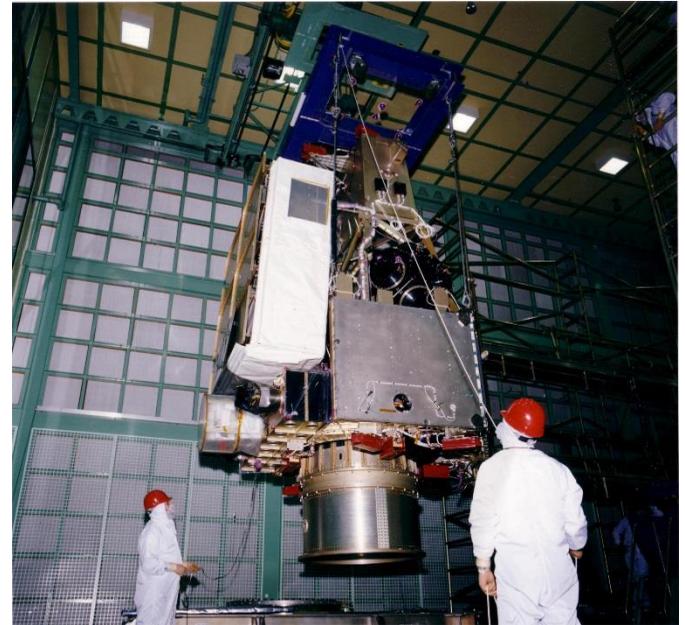
Executive Summary

- **TRMM is predicted to reenter on 17 June 2015**
- **Only approximately 12 pieces of debris from the TRMM spacecraft are expected to survive to reach the surface of the Earth**
- **TRMM debris have a very small chance (~2%) to fall on the United States**
- **The risk of anyone in the world being injured by TRMM debris is approximately 1 in ~4200**
 - The risk of 1 in 4200 means that if the same reentry were to occur repeatedly 4200 times, we would expect that only one person on Earth would be harmed.
 - NASA, the USG, and some foreign space agencies limit the risk from reentering space objects to less than 1 in 10,000.



Tropical Rainfall Measuring Mission (TRMM)

- **TRMM is a joint project of the U.S. and Japan**
 - U.S. is responsible for the satellite bus, four instrument sensors, and operations
 - Japan is responsible for the largest instrument (Precipitation Radar) and the launch of TRMM
- **Launched: 27 November 1997, from Tanegashima, Japan**
- **International Designator: 1997-074A**
- **U.S. Satellite Number: 25063**
- **Dry mass: 2630 kg (5798 lbs)**
- **Initial Operational Orbit: 350 km by 350 km, 35° inclination**
- **Decommissioned: 15 April 2015**
 - Expected re-entry date: 17 June 2015



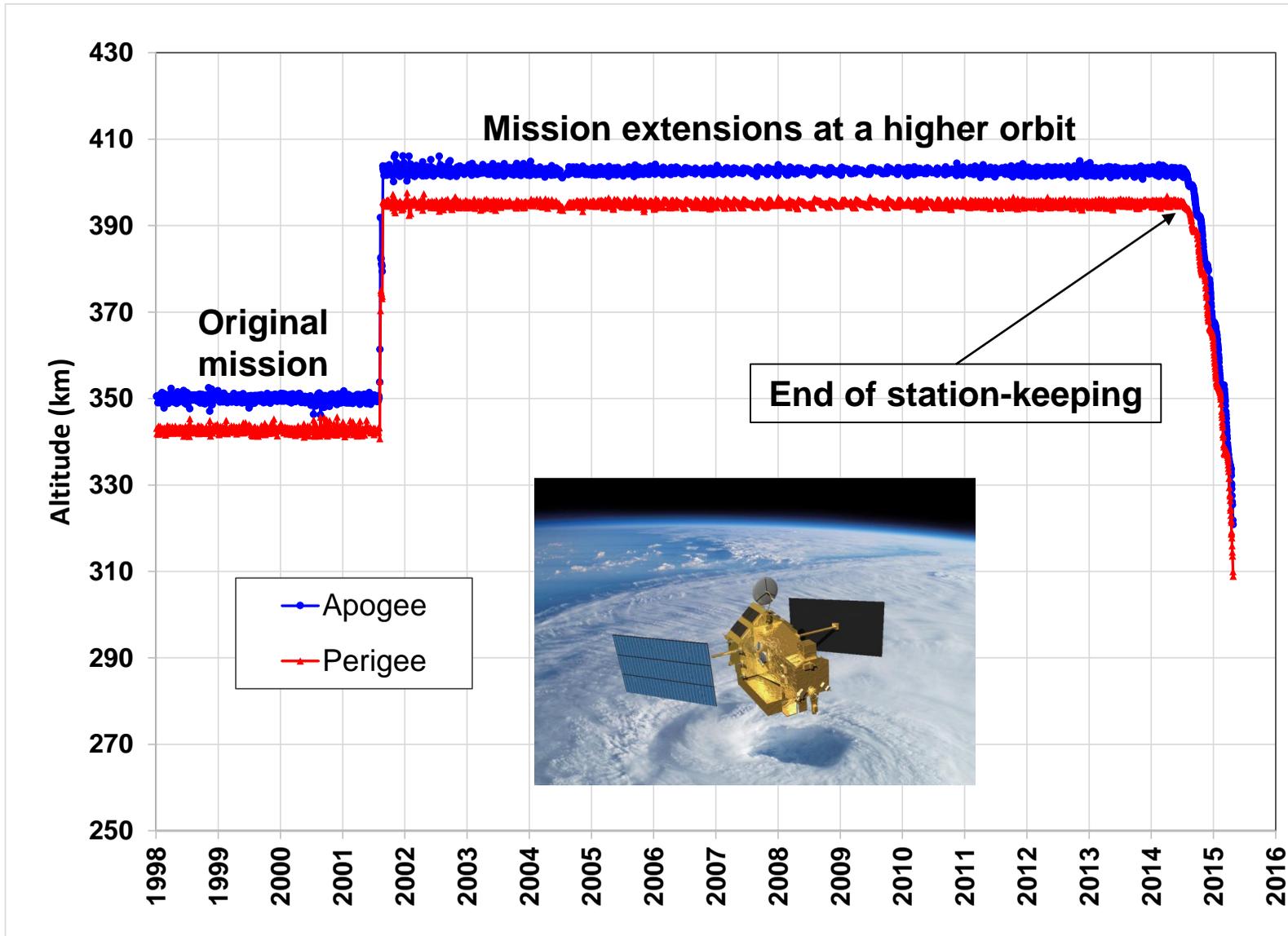


History of TRMM

- **TRMM was launched in 1997 for a 3-year mission**
 - Designed before orbital debris requirements were established, but planned for controlled re-entry
- **In 2001, the mission was given extensions until 2005, when residual propellant would reach the minimum required for controlled reentry from 400 km altitude**
 - TRMM was boosted to a higher orbit (400 km) to conserve fuel
- **After considerable analysis and review, TRMM was relieved of the controlled reentry requirement to prolong its mission until the Global Precipitation Measurement (GPM) spacecraft could be launched (then predicted to be 2010, actually launched in February 2014)**
 - Rationale was that TRMM, through its hurricane tracking and other capabilities, had the potential to save lives, out-weighting the risk of human casualty from uncontrolled reentry
- **NASA ceased station-keeping maneuvers of TRMM near the end of the spacecraft's fuel supply in July 2014**
 - TRMM has since drifted downward due to atmospheric drag and is expected to reenter in June 2015



Orbital History of TRMM





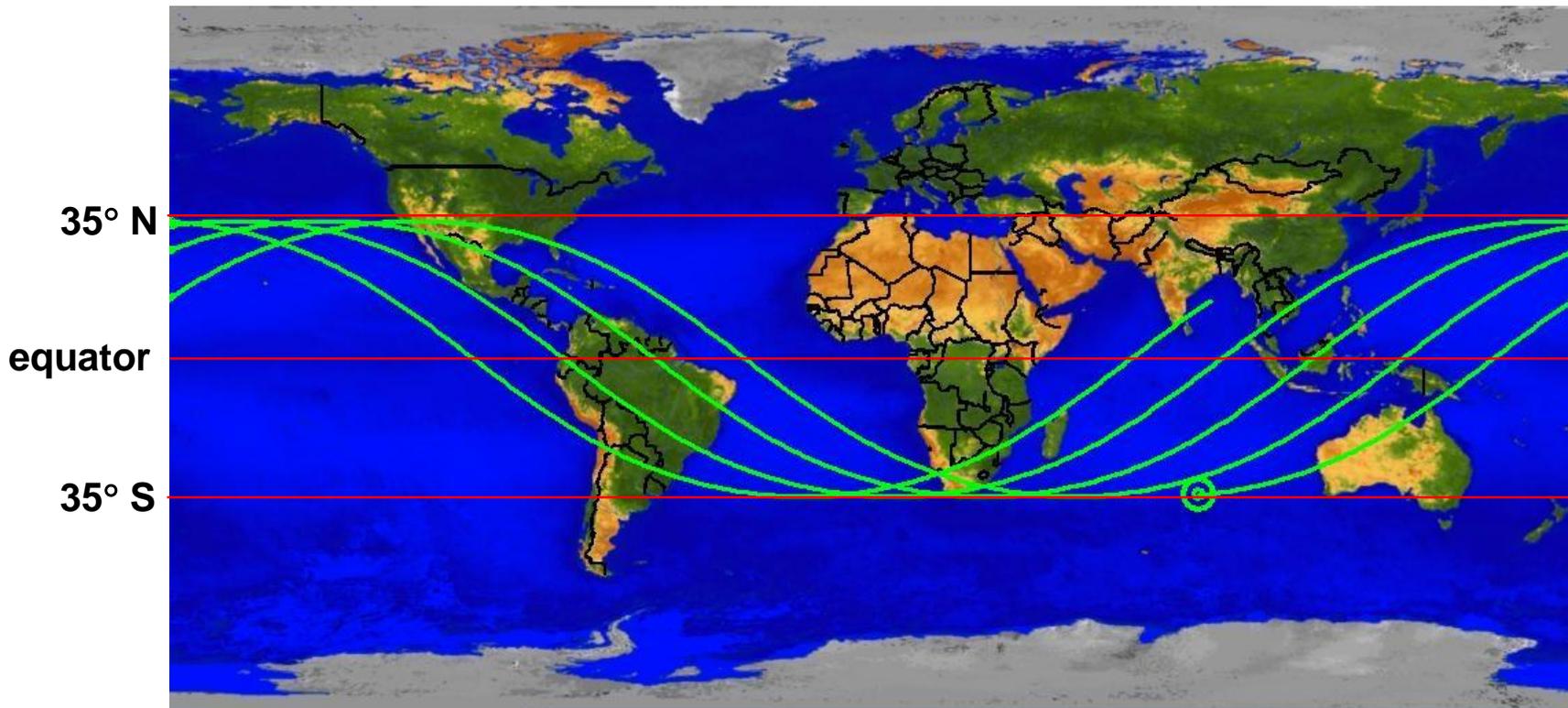
U.S. Reentry Predictions

- **The official source of reentry predictions for uncontrolled space objects is USSTRATCOM's Joint Space Operations Center (JSpOC).**
- **The normal procedure is for TIP (Tracking and Impact Prediction) messages to be prepared and released to the public (via the Space-Track.org website) at the following intervals:**
 - **T – 4 days, T – 3 days, T – 2 days, T – 1 day, T – 12 hours, T – 6 hours, and T – 2 hours**
- **TIP messages provide the best estimates of reentry time and location but have large uncertainties. Even at T – 2 hours, the uncertainty of reentry time is on average +/- 25 minutes for nearly circular orbits. This equates to +/- 12,000 km on the Earth.**
- **A final, post-reentry assessment message is normally issued within a few hours of reentry.**



Current Prediction of TRMM Reentry

- JSpOC's most recent prediction indicates that TRMM will reenter on 17 June



TRMM Groundtrack, 1200-1830 EDT, 26 April 2015



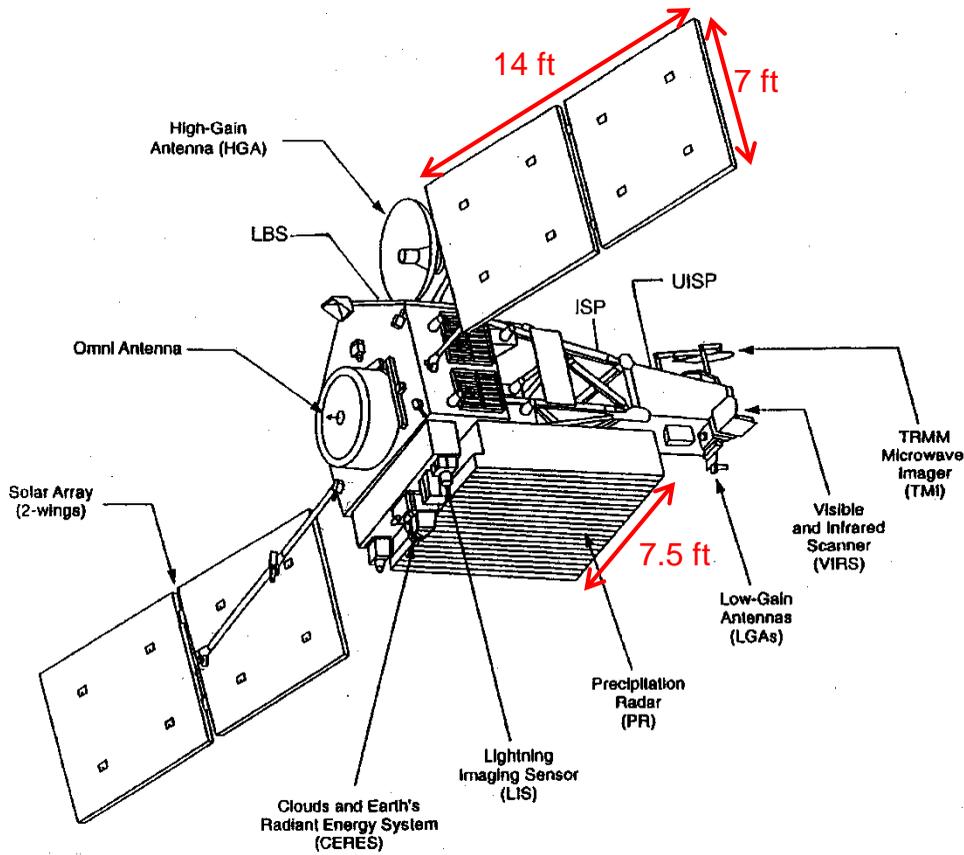
NASA Reentry Risk Capability

- **NASA's highest fidelity software program for reentering satellites is called ORSAT: Object Reentry Survival Analysis Tool. The program:**
 - Assesses spacecraft, launch vehicle stage, and other human-made space object component survivability during atmospheric entry from sub-orbital, orbital, and deep space trajectories.
 - Assesses human casualty risk associated with uncontrolled reentries.
 - Characterizes surviving debris footprints associated with controlled reentries for the purpose of avoiding inhabited regions and the Antarctic permanent ice pack.
- **ORSAT has supported many NASA, DoD, and other domestic and foreign programs during the past two decades.**

The principal outputs of ORSAT are component demise altitude or location, surviving mass, and kinetic energy of impact.

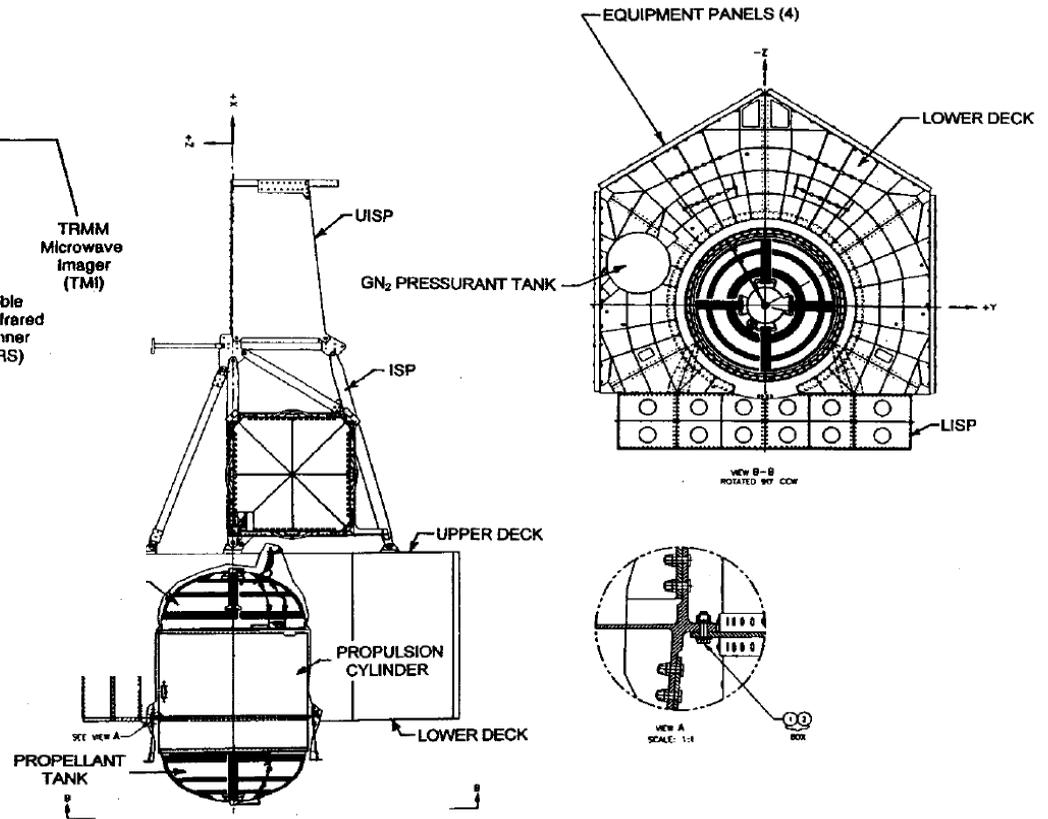


Sketches of TRMM



TRMM spacecraft with solar arrays deployed

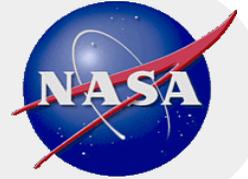
Sketch of TRMM propulsion cylinder



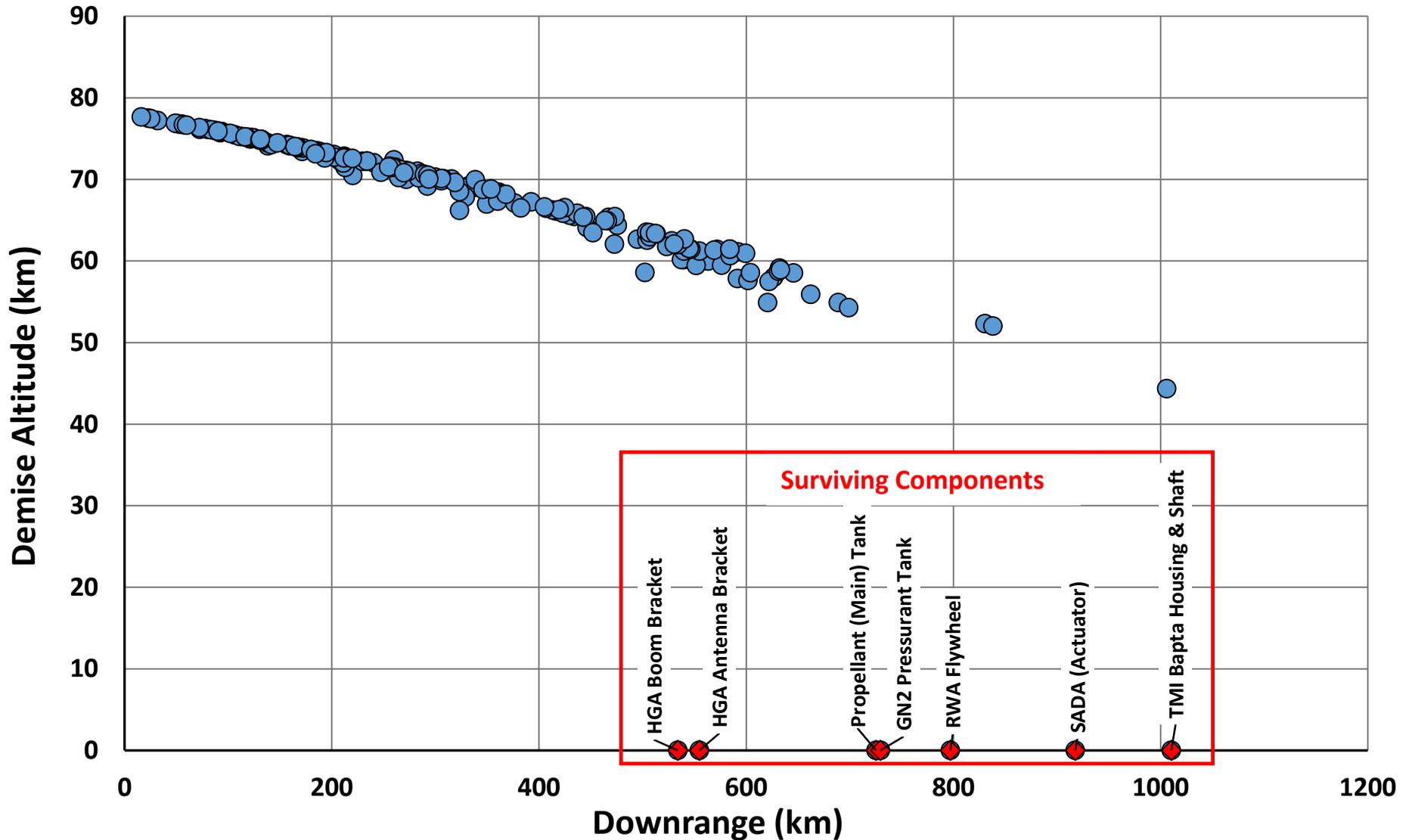


TRMM Casualty Risk Assessment

- **NASA conducted a detailed reentry risk assessment for TRMM in 2002**
 - Due to a lack of detailed information of some components, only ~91% of the TRMM dry mass was modeled
 - Number of potentially hazardous objects expected to survive: 12
 - These objects include two propellant tanks, a nitrogen pressurant tank, four Reaction Wheel Assembly (RWA) flywheels, two Solar Array Drive Assembly (SADA) actuators, a High Gain Antenna (HGA) boom bracket, a HGA antenna bracket, and a TRMM Microwave Imager (TMI) Bearing and Power Transfer Assembly (BAPTA) housing and shaft
 - Surviving objects are metallic (titanium alloys), nothing toxic
 - Total mass of objects expected to survive: 112 kg (247 lbs, ~4% of the dry mass)
 - Estimated human injury risk (updated in 2015): ~1 in 4200
 - The risk of 1 in 4200 means that if the same reentry were to occur repeatedly 4200 times, we would expect that only one person on Earth would be harmed.



Downrange Spread of TRMM Surviving Debris





Summary

- **TRMM is expected to reenter on 17 June 2015.**
- **The predicted human injury risk from uncontrolled-reentry TRMM debris is approximately 1 in 4200.**
 - The risk of 1 in 4200 means that if the same reentry were to occur repeatedly 4200 times, we would expect that only one person on Earth would be harmed.
 - NASA, the USG, and some foreign space agencies limit the risk from reentering space objects to less than 1 in 10,000.
- **TRMM is a moderate-sized space object. Uncontrolled reentries of objects more massive than TRMM are not frequent, but neither are they unusual.**
- **Since the beginning of the space age, there has been no confirmed report of an injury resulting from reentering space objects.**
- **DoD and NASA are monitoring the decay and reentry of TRMM carefully.**