The Launch of Gorizont 45 on the First Proton K/Breeze M

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Introduction

The first successful launch of a Proton K/Breeze M carrying Russia's Gorizont 45, lifted off from the Baikonur Cosmodrome at 0259Z on 6 June 2000. This was the first non-cooperative, non-historic Russian geosynchronous launch since the 5th rev ascending node injection of Cosmos 1940 in 1988. It was also the first non-historic deep space launch since the breakup of the former Soviet Union, and the subsequent commercialization of Russia's launch facilities. A great amount of detailed pre-launch information was available on the World Wide Web, including the date and time of the launch, the fact that the Proton upper stage was the new Breeze M and not the older Block DM, detailed performance characteristics of the Breeze M, and somewhat ambiguous details of the expected launch scenario. Based on this information, we were able to provide sensor tasking information that allowed all relevant sensors to track the payload in all of its orbits up to synchronous orbit.

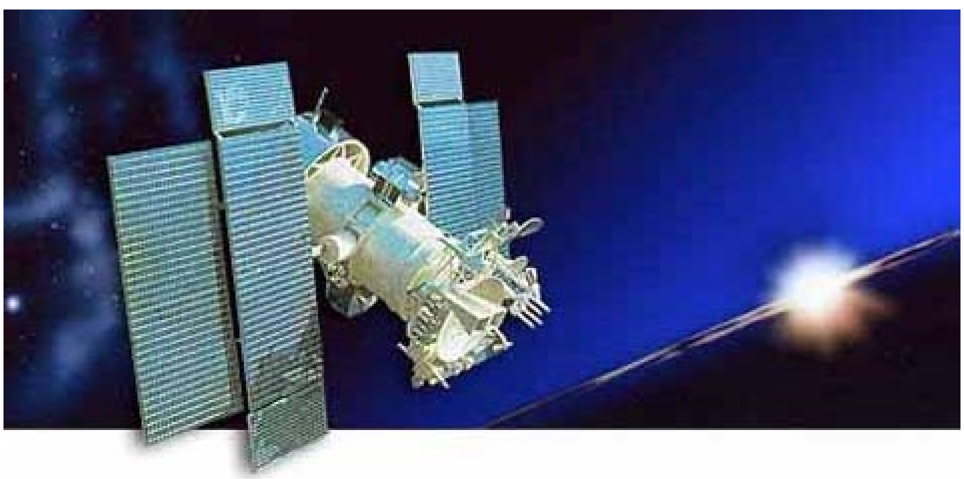

Figure 1 Drawing of a Gorizont payload from the Intersputnik web site.

The mission was nominal with respect to the pre-launch open source information. Each of the Space Surveillance Network (SSN) sensors with visibility tracked every object in parking, intermediate transfer orbit, and geosynchronous transfer orbit (GTO). However, a significant delay occurred before tracking the payload and rocket body in geosynchronous drift orbit. The rocket body was eventually found in a synchronous drift orbit as a SBV UCT by Millstone analysts. The payload was eventually found by ALTAIR from a search elset passed on by Millstone.

Millstone Hill Radar had a minor tracking role. Its first visibility was of the external fuel tank after the payload was separated from the rocket body into geosynchronous drift orbit. However, Millstone provided significant analysis support to the Space Control Center (SCC), which was inadequately prepared for this non-historic scenario. SBV provided significant contributions in searching for the payload and rocket body after injection into geosynchronous drift orbit. SBV successfully found the rocket body, and was the sole source of observations on it for two weeks. ALTAIR found the payload based upon a postulated search element set provided by Millstone.

Gorizont 45 (SCC #26372, referred to as Gorizont 33 by the SCC) is located at 145º east longitude, visible to ALTAIR radar, and both the Diego Garcia and Maui GEODSS sensors. The satellite has an expected on-orbit lifetime of 3 to 5 years. This Gorizont is owned and operated by Russian Satellite Communications Company (RSCC). Intersputnik, which operates other Gorizont satellites, provides a satellite system description on their web page http://www.intersputnik.com/gorizont.shtml.

Pre-Launch Information and Planning

This is the first Russian deep space non-historic launch since the dissolution of the former Soviet Union, the commercialization of much of the Russian space industry, and the age of the World Wide Web. International Launch Services (ILS), a multi-national partnership of Lockheed Martin, Krunichev and RSC Energia, markets the Proton/Breeze M for commercial customers, as well as Atlas. ILS makes available the Proton Launch System Mission Planner's Guide [http://www.ilslaunch.com/ILS/launch_services/mpg/pmpg_r4.pdf] that includes details of the Proton Breeze M systems and launch scenarios. From this document we were able to understand most of the differences between Block DM and Breeze M launches. However, there was misinterpretation before launch about the use of a "high-energy" transfer orbit illustrated in figure 2. We now believe that the Proton / Breeze M can insert payloads up to ~2,500 kg directly into geosynchronous drift orbit from the geosynchronous transfer orbit. Vehicles with greater mass will require the use of the high-energy geosynchronous transfer orbit as illustrated in figure 2.

The first three stages of the Proton cannot insert the Breeze M and attached payload into parking orbit because Breeze M has a much greater mass than the Block DM. Thus the first burn of the Breeze M inserts itself into parking orbit. This has the effect of leaving nothing in the parking orbit after Breeze M insertion into transfer orbit.

The second Breeze M burn places it into an intermediate transfer orbit (in this case with an apogee of ~5,000 km), and the third burn places it into a geosynchronous transfer orbit (GTO). The Breeze M sheds its toroidal shaped external fuel tank in this GTO.

The fourth burn, in this case, was into geosynchronous drift orbit. For heavier payloads another intermediate 'high-energy' GTO is necessary. The Breeze M separates from the payload after the fourth burn, leaving itself in either geosynchronous drift orbit (GDO) or 'high-energy' GTO.

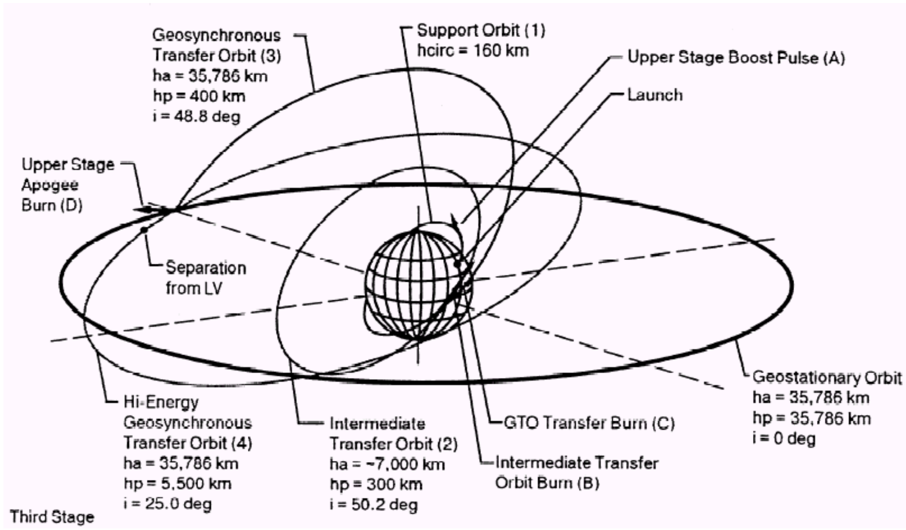

Figure 2 Launch scenario to geosynchronous orbit using the Proton/Breeze M.

Millstone analysts, based upon the pre-mission information, generated three postulated launch scenarios using the MIT/LL Interactive Scenario Designer (ISD). These postulated folders, with intermediate transfer orbit apogee heights of 5000 km, 6000 km and 7000 km, were used at Millstone for analysis, and were provided in advance of launch to ALTAIR.

The three scenarios, with apogee heights of 5000 km, 6000 km and 7000 km, had inclinations of 50.3º, 50.1º and 50.0º respectively. Launch designers strive to minimize the necessary total velocity change to GDO by optimizing the apogee height / inclination of the transfer orbits. The Proton / Block DM normally exhibits this by choosing a 48.8º inclination for its GTO from its 51.6º inclination parking orbit. We generated a model for the Breeze M multiple transfer orbit scenario assuming an attempt to minimize total velocity change, using a simple impulsive burn calculation. The results of this model are shown in figure 3. This model accurately calculates the normal Russian 48.8º inclination GTO.

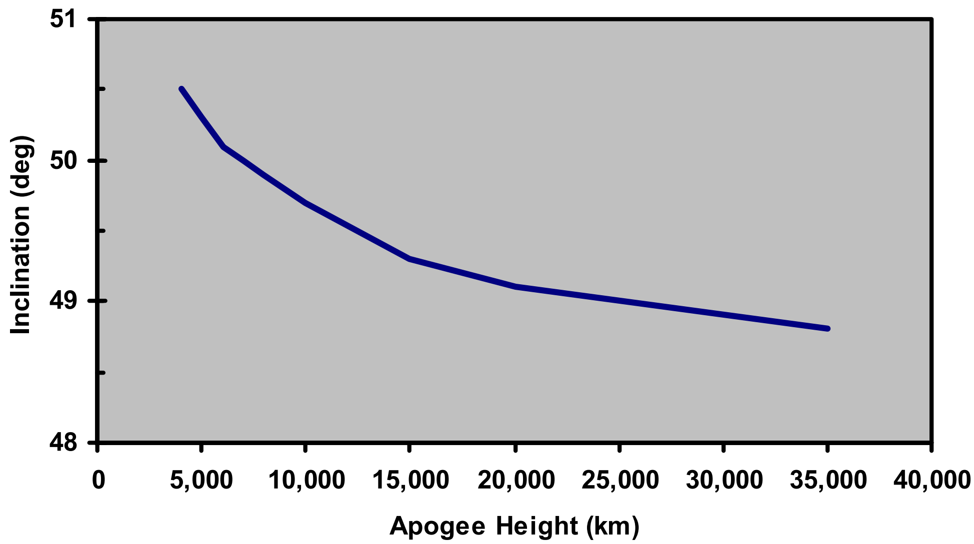

Figure 3 Model calculation of the inclination of the intermediate transfer orbit as a function of its apogee height. This model accurately calculates the 48.8º inclination of the normal Russian GTO.

This model is important if the need arises to search in the intermediate transfer orbit, since it reduces a two-dimensional search space, into a one-dimensional search. In this case the search space in inclination is small, from the 51.6º inclination parking orbit to the 48.8º inclination geosynchronous transfer orbit. However, for future missions using a high-energy transfer orbit with a perigee height somewhere between a few thousand kilometers and 35,000 km, the inclination can vary between the 48.8º GTO and the 1.5º GDO. Figure 4 shows the model calculation for the high-energy transfer orbit case. Without this model for reducing the search to a one-dimensional space it is unlikely that even wide field of view optical systems could be successful in finding the payload in the high-energy transfer orbit.

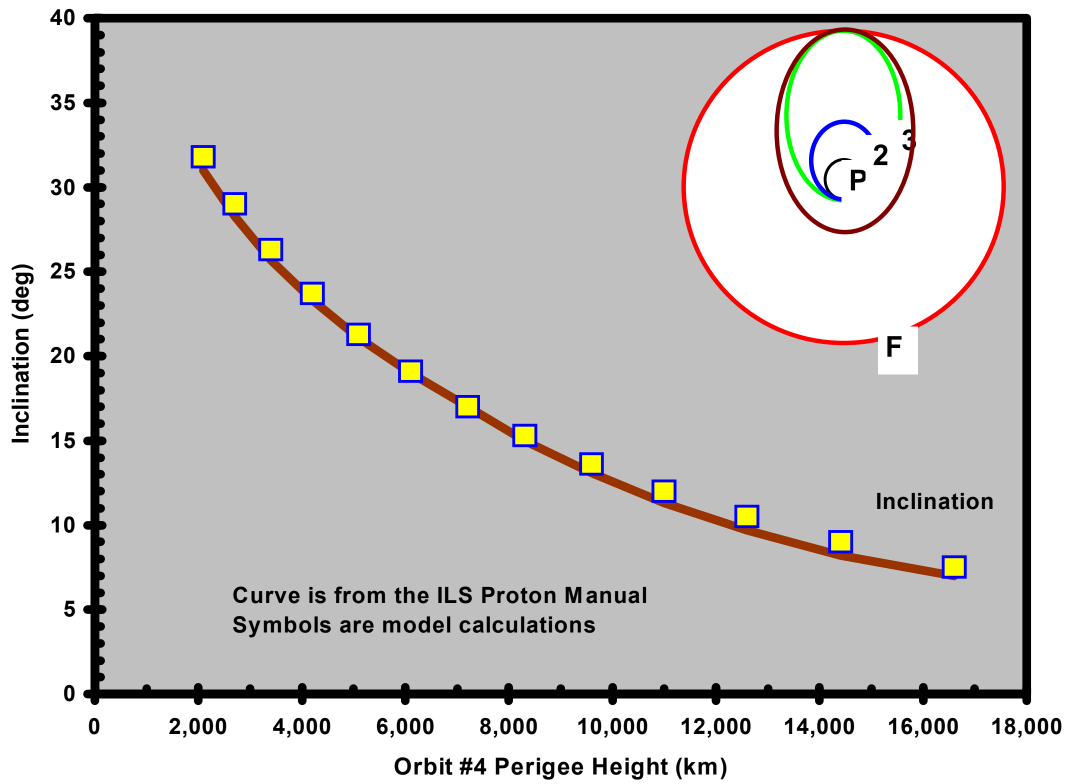

Figure 4 Model calculation of the inclination of the high-energy transfer orbit as a function of its perigee height. The curve is from the ILS Proton Systems Manual. The points are the model calculations, which agree to within 1º of the rigorously derived and published values.

Mission Events

Launch to Geosynchronous Drift Orbit Insertion

The ground trace in figure 5 illustrates the launch scenario and sensor coverage of the Gorizont 45. Figure 6 is a 3-D representation of the launch scenario. Table 1 summarizes the launch coverage timeline. All figures use the same color coding for the individual orbits.

Liftoff occurred at 2000 158/0259Z, at the published opening of the launch window.

ALTAIR acquired and tracked the payload and attached upper stage in the rev-0 parking orbit, sent its observations and orbital element set.

We have no information regarding whether Ascension tracked the complex in the parking orbit, through and after burn into the intermediate transfer orbit. Typically Ascension provides pre and post burn observations and elsets.

Fylingdales acquired and tracked the complex in the intermediate transfer orbit, and transmitted observations and elset to the SCC. ALTAIR acquired and tracked the complex off of Fylingdales handover element set. ALTAIR sent observations and orbital element sets to the SCC.

Fylingdales presumably acquired track using its standard search fence. If it had not tracked the complex, ALTAIR would have searched on the Millstone provided postulated orbital element sets as described above. We were not able to operate the Interactive Scenario Designer (ISD) during the launch events, but the thorough pre-launch calculations, and Fylingdales search and track performance, precluded the need for further calculations.

Millstone provided the SCC with the parameters for a search elset for the geosynchronous transfer orbit based upon our pre-mission analysis, and ALTAIR's measured parameters of the intermediate transfer orbit. A postulated elset was passed on to Fylingdales, which acquired and tracked the complex in GTO. We did not receive Fylingdales observations and elset directly, but did receive an elset from the SCC derived from the Fylingdales observations. Fylingdales tracks of the complex in the intermediate and geosynchronous transfer orbits were critical for the successful tracking of the complex up to synchronous orbit.

At this point we recommended that the SCC task Feltwell, Misawa, MOS, and Diego Garcia to search for a UCT in the vicinity of 55º longitude, drifting toward 145º longitude.

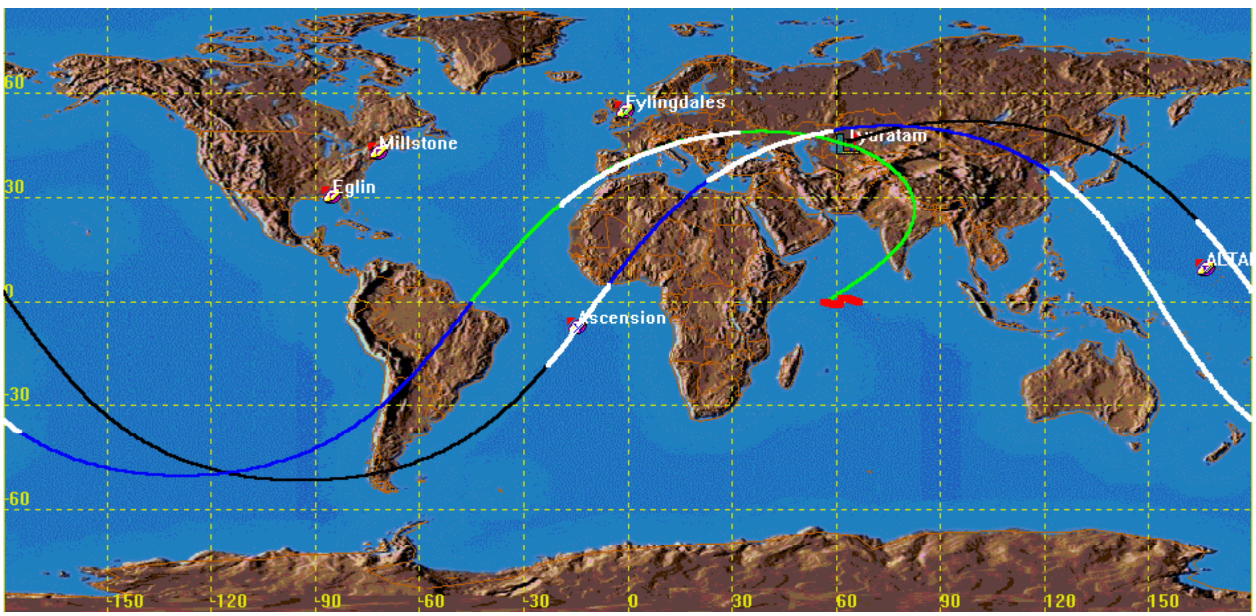

Figure 5 Ground trace of the Gorizont 45 launch. Each orbit is uniquely colored. White segments indicate sensor coverages.

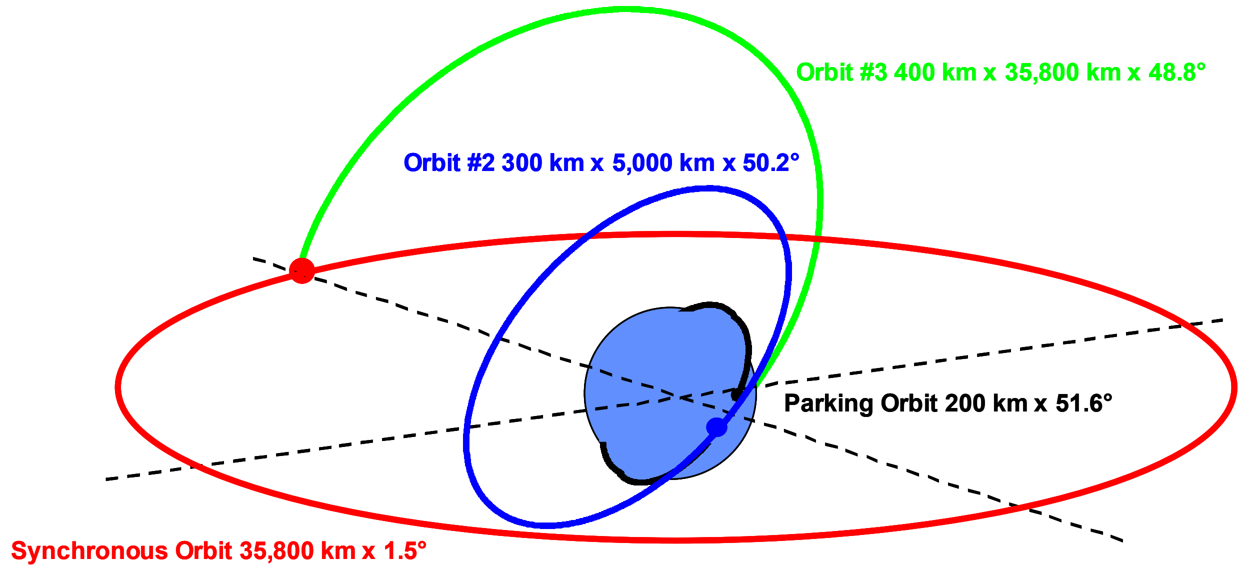

Figure 6 3-D representation of the Gorizont 45 launch

***Table 1** Timeline of important events following the launch of Gorizont 45 through shortly after insertion into the geosynchronous drift orbit. Color-coding is consistent with the launch coverage figures. ALTAIR was the first SSN sensor with visibility of the parking orbit, as it is for all synchronous launches from Baikonur.*

Parking Orbit 220 km X 51.6º		
day 158	02:59	Launch
	03:36	ALTAIR elset and observations Ascension acquisition/elset?
Intermediate Transfer Orbit 265 X 5,000 km X 50.3º		
	04:11	Ascending node injection into transfer orbit
	04:45	Fylingdales elset
	05:17	ALTAIR elset; acquisition from FYL elset
Geo Transfer Orbit 380 X 35,000 km X 48.8º		
	06:37	Perigee, ascending node injection into GTO Fylingdales track to SCC
	09:09	SCC elset from Fylingdale data
GEO drift orbit 56º drifting ~10º/day toward 145º		
	11:48	Apogee, descending node injection into GEO drift orbit
	17:04	ALTAIR elset on RB in GTO
	17:32	MHR elset on tank in GTO
day 159		HAX images confirm external tank in GTO

Post Geosynchronous Drift Orbit Insertion

Following insertion of the payload and rocket body into geosynchronous drift orbit ALTAIR and Millstone tracked the remaining external fuel tank in the geosynchronous transfer orbit. Both narrow band radars identified the object as the external tank based upon their measured RCS signatures. The following day HAX imaged the external fuel tank, positively confirming that it was not attached to the rocket body and payload (as was being opined by some SCC analysts).

The orbital element set for the external fuel tank in transfer orbit was published as elset #1 for the payload, as payload data in geosynchronous drift orbit were not available for the next seven days.

Following injection into geosynchronous drift orbit, the payload and upper rocket body were lost. SBV was used to search the geosynchronous belt for UCTs. Two geosynchronous UCTs were detected in the area of interest on day 159. There were insufficient observations to derive element sets, though the locations were reported to the SCC on day 160. By day 164 more observations were collected, and the UCTs were identified.

Summary

The space surveillance network was very successful in tracking this non-historic launch up to geosynchronous drift orbit. This was achieved by good pre-mission planning at Millstone, good coordination through the SCC, and good tracking by the available sensors, especially Fylingdales.

However, the payload was not tracked and identified in its geosynchronous drift orbit for several days until it came into ALTAIR's coverage. SBV was useful, but it cannot be reliably tasked to search a region of the geosynchronous belt. We do not know whether the ground based optical and passive radar sites were tasked to search for the payload, and if so whether they looked for it.

It is important for the next Breeze M launch to continue the pre-mission analysis necessary to accurately cue the network to acquire the payload complex in all orbits, for the sensor network to respond as well as it did for this launch, and that the optical and passive sensors be tasked with a good postulated geosynchronous drift orbit elset.

Acknowledgements

Many individuals and organizations contributed to this effort. Dan Collins originally identified the launch scenario differences between Block DM and Breeze M deployments. He and I generated postulated mission orbital element sets using the MIT/LL Interactive Scenario Designer (ISD), generated STK ground traces, calculated 'nominal' SSN sensor timelines, and prepared a briefing given to the SCC launch officer, the CIC, and other customers. Sigrid Close, with my assistance, prepared the pre-launch memo for ALTAIR and Millstone launch coverage that properly alerted ALTAIR for the upcoming non-historic launch. Marilyn Lewis analyzed the post geosynchronous drift orbit insertion SBV UCTs and provided other analysis support. Fylingdales radar's tracking of the intermediate and geosynchronous transfer orbits was critical for successful coverage of the launch up to geosynchronous drift orbit insertion.

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