Unknown GEO Object 2000-653A / 90007 Identified as Prowler

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Abstract

Space Shuttle mission STS 38 is officially acknowledged to have deployed only a single payload, which is known to be a geosynchronous communications satellite, operated by the National Reconnaissance Office. It has since leaked out that STS 38 deployed a second payload: an optically stealthy, geosynchronous satellite inspector, named Prowler.

In 1998, hobbyists discovered a bright unknown GEO object, with optical and orbital characteristics of a satellite, which they call 2000-653A / 90007. By early 2010, independent GEO satellite observation networks had accounted for every single GEO satellite acknowledged to have been launched, yet 2000-653A remained unidentified. Analysis of its optical and orbital characteristics, and other relevant facts, reveals great consistency with the emerging Prowler story, resulting in a strong circumstantial case that 2000-653A is Prowler.

CONTENTS

Acknowledgements

Scott Campbell and Greg Roberts, who specialize in observing GEO objects, accounted for the vast majority of observations of positions and brightness of 2000-653A / 90007 and/or known HS-376 satellites used in this study. Thank you both.

Derek Breit, Tim Luton, Ian Roberts, and Brad Young are relatively new to GEO observing, but still managed to contribute some useful observations of positions and brightness of 2000-653A / 90007 or known HS-376 satellites. Thank you all.

Thank you Mike McCants, for providing orbital elements of 2000-653A, and your wonderfully accurate int3 orbit propagator.

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1. Introduction

This report presents optical and orbital evidence that the unknown GEO object 2000-653A / 90007 is Prowler - the unacknowledged second satellite launched in 1990 on space shuttle mission STS 38.

The presentation is chronological. Sections 2 through 4, respectively present the relevant facts of STS 38, the discovery of 2000-653A, and the emerging Prowler story.

Section 5 describes how the U.S. Government's status in 1990 as the sole source of orbital data made it easy to conceal Prowler from the public, and how the subsequent development of independent hobbyist and professional scientific observation networks, enabled it to be identified in 2010, through a process of elimination.

Sections 6 and 7 respectively present the optical and orbital characteristics that circumstantially identify 2000-653A as Prowler, based on what has been revealed about it, and reasonable inferences drawn there from. Its brightness closely matches that of other satellites of the same bus; its orbit is of a type occupied almost exclusively by abandoned satellites, and has several characteristics that strongly correlate with the Prowler story.

Section 8 corrects the deceptive information in the USSTRATCOM (U.S. Strategic Command) satellite catalogue entries related to the STS 38 launch, and proposes that Prowler's existence be acknowledged by adding an entry for 1990-097E, and that 2000-653A be re-designated as such.

Section 9 summarizes the findings and conclusions and offers suggestions for further study.

2. STS 38

Space shuttle mission STS 38 was launched on November 15, 1990, from Cape Canaveral, on a highly classified, dedicated DoD mission. It landed five days later, at the Kennedy Space Center, in Florida.

Prior to the launch, Aviation Week & Space Technology identified its payload as a satellite called AFP-658 (Air Force Project 658), with a "gross weight of 22,000 lbs," carrying "digital cameras and other sensors, which will focus on the Persian Gulf region to provide both strategic and tactical reconnaissance information for Desert Shield air and ground commanders there." It would also "carry an upper stage to lift its orbit about 400 NM from the shuttle's."[1]

In an effort to gather information regarding the expected satellite deployment, the author of the present report encouraged and supported visual observations of STS 38 by the public.[2] Observers in Florida, Texas[3] and Arizona[4], reported a bright, reddish satellite, flashing about once per second, orbiting in formation with Atlantis. As expected, it soon manoeuvred and the observers lost track of it. Subsequent searches did not reveal the LEO (low Earth orbit) imagery intelligence satellite predicted by AV Week, and its existence has long since been discounted.

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[1] Edward H. Kolcum, "Next Shuttle Flight to Carry Sensors for Providing Intelligence on Persian Gulf," *Aviation Week & Space Technology*, October 22, 1990, pg. 29.
[2] Ted Molczan, "STS 38 Visual Observation Guide," *sci.space*, 13 Nov 90 13:12:28 GMT.
[3] Ted Molczan, "USA 38 Payload Observed," *sci.space*, 17 Nov 90 04:21:37 GMT.
[4] Private e-mail correspondence with an astronomer. Nov 17-19, 1990.

The satellite seen in formation with Atlantis was eventually determined to have been SDS 2-2 (aka SDS B-2 and Quasar B-2), the second of a new generation of National Reconnaissance Office (NRO) communications relay.[5] But a significant loose end remained in the STS 38 story.

2.1 One Too Many Rocket Bodies

USSTRATCOM's (U.S. Strategic Command's) satellite catalogue acknowledges STS 38 to have launched a single satellite, which it calls USA 67, to which it attributes two rocket bodies. Presumably, USA 67 is SDS 2-2, but 2nd generation SDS satellites employed a single PKM (perigee kick motor), which raised their apogee to a fraction of the operational altitude, leaving all remaining manoeuvres to their integral liquid apogee motor; therefore, SDS 2-2 could not have jettisoned a second rocket body.

A satisfactory explanation of USSTRATCOM's second rocket body would remain elusive until the public gained a fuller understanding of what was in orbit about the Earth, and hobbyists were contributing to that effort.

3. Hobbyists Discover a Brightly Flashing Unknown GEO Object

On 1998 July 31 UTC, Ed Cannon, of Austin, Texas, spotted a series of bright flashes from an unknown object in GEO.

Ed's observing partner, Mike McCants, reported that it "flashed to about magnitude 3 every 46.0 seconds" over a five minute period, before gradually fading to magnitude 9. He also reported, "multiple secondary brightenings," that were "almost (but not exactly) 1/2 way between the primary flashes," that "started out about 5th magnitude and decreased to about 10th magnitude," which he assumed were "caused by reflection from the solar panels onto the main body of the spacecraft."[6]

It is noteworthy that Mike classified the object as a satellite, instead of a rocket body or debris, based on its bright, specular reflections and flash pattern. He obtained a couple of timed positions, sufficient to roughly estimate its orbit, enabling him and Ed to spot it again the next night, and several more times over the next couple of months.

In his report on the 1998 Aug 01 UTC observation, Mike reported on the object's complex pattern of flashing, "About 04:37, the secondary brightenings were timed at 19.9, 23.9, and 25.7 seconds after the preceding primary maximum. A time of 23.0 would be 1/2 way between the primary maxima which occur every 46.0 seconds."[7] A rotating satellite with reflective appendages around its axis of rotation could account for such a pattern.

The object was eventually lost, and was not seen at all in 1999. Ed Cannon unknowingly spotted it again in June 2000, reporting "I've been watching an UNID geosynch with a flash

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[5] Dwayne A. Day, "Out of The Shadows: The Shuttle's Secret Payloads," *Spaceflight*, Vol. 41, Feb 1999.
[6] Mike McCants, "Ed Cannon discovers another geosync flasher!," *SeeSat-L*, archived Fri, 31 Jul 1998 14:11:16 CDT, <http://satobs.org/seesat/Jul-1998/0413.html>.
[7] Mike McCants, "Ed Cannon's new geosync flasher," *SeeSat-L*, Sat, 1 Aug 1998 11:46:22 CDT, <http://satobs.org/seesat/Aug-1998/0001.html>.

period of about 24 seconds (brightest maxima about +4.5?) for a few nights but have not identified it yet …”[8]

After a subsequent observation, Ed reported, “Its brightest flashes are at least +4, easy in binocs and probably would be one-power from a good site on a moonless night. Its flash times are consistently asymmetrical (~25/23.5), so its fundamental period seems to be 48+ seconds.”[9]

Ed’s comment about it probably being “one-power” is his way of saying that some of its flashes were bright enough to be seen with the unaided eye. This kind of behaviour has been observed from a number of geosynchronous satellites, due to specular reflections from solar arrays or antennas. It is a strong indication of a satellite, instead of a rocket body or debris.

The object was assigned the hobbyist designations 2000-653A and 90007, and eventually was recognized to have been the same one discovered in 1998. It has been observed ever since, and its orbit and optical characteristics have been determined. Scott Campbell observed it on 2011 Jan 02, located at 91.94 W, and drifting west at 0.2 deg/d. Mike McCants determined the following 2-line orbital elements:

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1 90007U 00653A   11002.06293503  .00000000  00000-0  00000-0 0    05
2 90007  13.1245  31.7158 0046045 130.0199 230.3936  1.00217850    01
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4. The Story of Prowler Emerges

A 2004 news report on a controversial U.S. stealth satellite program revealed that an unacknowledged second satellite had been launched on STS 38: “an experimental and highly classified satellite called ‘Prowler’,” that had “stealthily maneuvered close to Russian and presumably other nations’ communications satellites” in geosynchronous orbit.[10] A 2008 article on the hidden meaning in military patches reported a second crew patch of STS 38, that appeared to hint at the unusual secrecy of their mission.[11]

Public knowledge of the orbits of objects in GEO was insufficient for anyone to suspect that 2000-653A / 90007 was Prowler, but that was about to change, due to the development of independent observation networks.

5. All of the Pieces of the Puzzle

5.1 U.S. was Sole Source of Public Orbital Data in 1990

To facilitate Prowler’s mission to stealthily rendezvous with, and inspect Russia’s geosynchronous satellites, the U.S. took the unusual step of not publicly acknowledging its launch. Since satellite launches are almost impossible to conceal, Prowler was provided cover by launching it together with another secret military satellite, on the classified DoD shuttle mission STS 38, and then publicly acknowledging the deployment of only one of them.

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[8] Ed Cannon, “Two flashing geosynchs,” *SeeSat-L*, Wed Jun 07 2000 - 10:15:53 PDT, <http://satobs.org/seesat/Jun-2000/0168.html>.
[9] Ed Cannon, “00653A/90007 obs,” *SeeSat-L*, Fri Jun 16 2000 - 03:17:13 PDT, <http://satobs.org/seesat/Jun-2000/0313.html>.
[10] Robert Windrem, “What is America's Top-Secret Spy Program?,” *NBC News*, Dec 9, 2004.
[11] Roger Guillemette and Dwayne A. Day, “Space Age Hieroglyphs,” *The Space Review*, Aug. 25, 2008.

At the time, the U.S. government was, for all practical purposes, the sole worldwide source of public information on the precise orbits of high-altitude Earth satellites, which it withheld for nearly all of its military satellites. Whether Prowler's optical stealth technology proved sufficient to hide it from Russia's military space surveillance system is not known, but the absence of independent public sources of orbital data made it easy to hide it from the public, by simply not acknowledging its existence.

5.2 Independent Sources Arise

During the 1980s and early 1990s, a small group of hobbyists began to detect, track and publish the orbits of U.S. military satellites. Initially they concentrated on low Earth orbit, but in the mid-1990s a few began to observe some of the brighter Molniya and geosynchronous objects, including a small number which they could not immediately identify, but could categorize as U.S. military objects, because their orbits did not match any of those for which official data was available. By 2007, several observers employed telescopic cameras to regularly observe a large number of U.S. military objects. They were able to identify some of them, and assigned the remainder independent IDs, e.g. 2000-653A / 90007.

By far the most significant independent public source of orbital data at present is the Russian-led International Scientific Observation Network (ISON), which was organized beginning about 2003, as a co-operative effort to detect, track and study geosynchronous debris. ISON's sensors also readily detect much larger objects, including satellites and rocket bodies. Since 2005, ISON's orbital elements have been included in the European Space Agency (ESA) annual series, *Classification Of Geosynchronous Objects*.

5.3 Identified Through a Process of Elimination

By early 2009, the efforts of hobbyists, and especially of ISON, had resulted in the discovery of more than 150 bright objects which were not in any of the orbits published by the U.S. government, and roughly matched the number of U.S. military satellites and rocket bodies acknowledged to have been launched into secret orbits. Through the efforts of hobbyists and ISON, about half had been correlated with their launch, and matched to a specific piece. During 2009 both groups continued to work to identify as many as possible of the remainder.

Reports published in early 2010 by hobbyists[12] and ESA/ISON[13] finally accounted for every single satellite and rocket body acknowledged to have been launched to GEO, including all of those for which the U.S Government withheld orbital elements.

Their findings were very similar overall, and in complete agreement on nine relatively bright objects that remained to be matched to a launch, which included 2000-653A / 90007 (UI.139 in ISON's catalogue). The hobbyist report tentatively correlated it with the STS 38 launch, but recommended further study, which led to the present report. The following two sections present the optical and orbital evidence that circumstantially identifies 2000-653A / 90007 / UI.139 as Prowler.

[12] Ted Molczan, "Identification of UI Objects in Classification of Geosynchronous Objects Issue 11," *self*, Jan 31, 2010. <http://satobs.org/seesat_ref/IDCOGO11/Identification_of_UI_Objects_in_COGO_11.pdf>
[13] R. Choc and R. Jehn, "Classification Of Geosynchronous Objects Issue 12," *European Space Agency*, February 2010, pp. 98-115. <http://www.secureworldfoundation.org/siteadmin/images/files/file_460.pdf>

6. Optical Characteristics Consistent With Satellite of Medium Size

Two experienced observers of GEO objects, who had seen 2000-653A / 90007, and were unaware that it could be Prowler, were asked to classify it as a payload, rocket body or debris. Ed Cannon, who discovered the object in 1998 and again in 2000, stated that his "best guess is that it has to be a payload." Kevin Fetter, who has long specialized in observing flashing objects in high altitude orbits, stated that "I would have to say, it's most likely a payload."

Observers consider 2000-653A to be a satellite, based on its optical characteristics, especially its occasionally brilliant specular flashes, and complex light curve, that are typical of rotating satellites with large reflective surfaces, such as solar arrays and antennas. Rocket bodies and debris may rotate and flash, but rarely produce such brilliant specular reflections. Asked whether he could recall any specific examples of GEO rockets or debris that sometimes flashed as bright as 2000-653A, Kevin Fetter stated that he did not "remember observing any rocket/debris in a high orbit, that flashes that brightly."

2000-653A's intrinsic brightness, mag 4.4 (range 1000 km, phase angle 90 deg), is equivalent in brightness to a 7 m diameter spherical satellite of average reflectivity.[14] Most satellites are not spherical, and differ in reflectivity, so that is only a rough guide; however, it seems safe to describe it as a satellite of medium size – at least several metres across in its largest dimension.

A source who learned in the mid-1990s that Prowler had been launched on the shuttle and that it was based upon the HS-376 bus informed me of those facts. This revelation suggested an important test of the hypothesis that 2000-653A is Prowler, by comparing its optical characteristics with those of known HS-376 satellites.

6.1 Brightness Consistent With Prowler's HS-376 Bus

Figure 1 plots 99 observations of 2000-653A and 134 observations of 40 different HS-376 satellites, on a scatter diagram of magnitude normalized to 1000 km range vs. phase angle, revealing a striking similarity. Standard magnitudes agree to within 0.1 mag, and coefficients of phase are similar. Since these plots are intended to compare the brightness of satellite buses, they exclude exceptionally bright specular reflections.

There are quite a few payloads and rocket bodies of similar standard magnitude, so the most that can be said is 2000-653A is consistent with HS-376, but it is a significant finding, especially considering that all other payloads and rockets have been accounted for.

HS-376 satellites are cylinders, about 6.6 m long, and 2.16 m in diameter. During their operational lives, they are spin-stabilized about the long axis. Their payloads are mounted on an electrically de-spun platform at one end. The spinning section rotates at 55 RPM during the operational life of the satellite, resulting in flashes at intervals of about one half second.

Observations of a small number of de-commissioned HS-376 satellites reveal somewhat longer flash periods, but there was great variability in the data, and no consistent pattern of behaviour, e.g. flash period versus time since decommissioning, that would enable meaningful comparison with 2000-653A.

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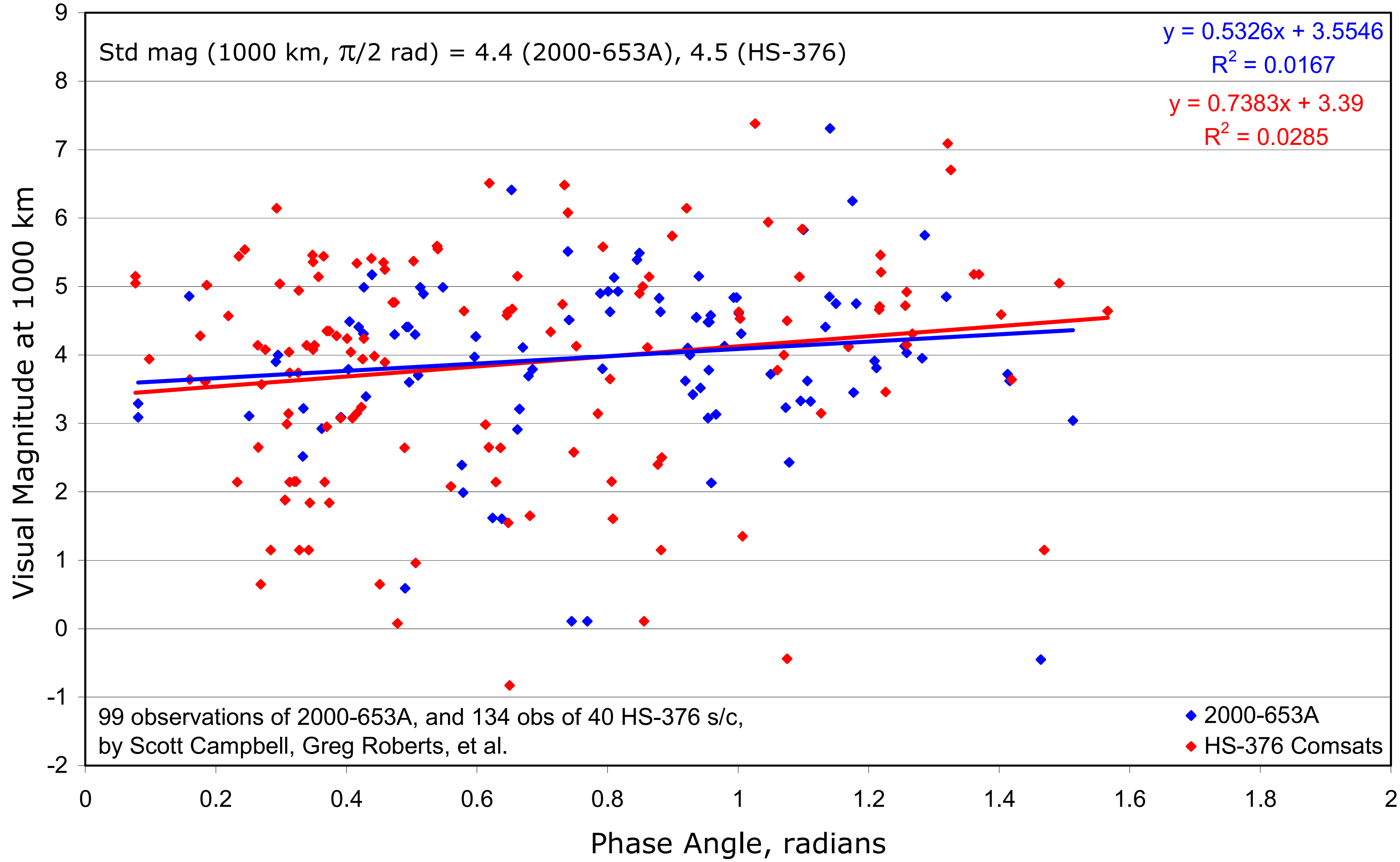
[14] Desmond King-Hele, *Observing Earth Satellites*, 1983, Fig.16 relates magnitude to range of spherical satellites of various diameters. It has proven to be a fairly reliable indicator of approximate satellite size.

Figure 1: 2000-653A / 90007 - Brightness Compared With HS-376 Comsats
Visual Magnitude at 1000 km Vs. Phase Angle



6.2 Similarity to LES-8

Lincoln Experimental Satellite 8 (1976-023A / 8746), launched to geosynchronous orbit in 1976, reportedly carries a plane mirror for R&D of optical signature suppression.[15] It, and its otherwise similar sister, LES-9, had been difficult to spot, even with telescopes, due to their small size, and lack of solar arrays, yet LES-8 was spotted with the unaided eye in early 2005, less than a year after it was decommissioned, due to brilliant specular reflections, strongly reminiscent of the mode of discovery of Prowler stealth satellite suspect 2000-653A, in 1998 and 2000.

That their now presumably anti-stealthy mirrors cause these objects to flash, is an intriguing possibility, that cannot be proved with the available evidence. With respect to the HS-376-based Prowler, reports of brilliant specular flashes from the HS-376 satellite B-SAT 1B (1998-024B / 25312)[16], show that HS-376 satellites can flash for other reasons. Prowler could have employed a mirror for stealth, which could be the source of its flashes, but it could have been stowed at decommissioning, in which case antennas and instruments might be causing it to flash.

7. Orbital Characteristics Consistent With Prowler Story

2000-653A / 90007's librating orbit makes it highly probable that it is a satellite, not a rocket body or debris. Its initial orbital inclination and plane correlate with Russia's geosynchronous satellite constellation at the time of STS 38, which reportedly were its primary targets. That it is librating over the western hemisphere suggests intended disposal of the no longer stealthy satellite out of sight of Russian territory. Its moderate orbital eccentricity appears to have been designed to mitigate the worst shortcomings of disposal in a librating orbit.

7.1 Librating Orbit Consistent with an Abandoned Satellite

2000-653A librates around the western stable point, 105 W, between 73 W and 136 W, with a period of about 964 days. A librating orbit is strong evidence of a satellite, because the vast majority of known objects in librating orbits are abandoned satellites, as shown in the following breakdown of objects librating around the eastern stable point, western stable point, or both.[17]

Objects	Eastern	Western	Both	Total
Known satellites	89	42	14	145
Known satellite debris	1	0	1	2
Known rocket bodies	17	1	2	20
Bright unknown objects	2	1	0	3
Total	109	44	17	170

All but one of the 43 known objects that librate around the western stable point are satellites, so statistically 2000-653A probably is a satellite.

7.2 Evidence of N-S Station Keeping, Consistent With STS 38

Since Prowler was intended to manoeuvre close to geostationary payloads, it could reasonably be expected to have entered a near zero degree inclination orbit, and performed regular north-

15 Allen Thomson, "Stealth Satellite Sourcebook," <http://www.fas.org/spp/military/program/track/stealth.pdf>

16 Kevin Fetter, "B-SAT B1, Gstar 4 video and ppas report," *SeeSat-L*, Sat Nov 14 2009 - 03:03:47 UTC. Confirmed in 2010 by Greg Roberts, Ed Cannon, Mike McCants, and Brad Young.

17 Compiled from R. Choc and R. Jehn, "Classification Of Geosynchronous Objects Issue 12," *European Space Agency,* February 2010, pp. 82-93, 110-111. <http://www.secureworldfoundation.org/siteadmin/images/files/file_460.pdf>

south station-keeping manoeuvres over its operational life, and there is support for that in 2000-653A’s present orbit. Propagating its orbit back in time reveals that its inclination was most recently at a minimum in September 1992, when it was less than 0.01 deg. That could have been the end of north-south station-keeping, indicating a primary mission of about 22 months after launch.

An alternative interpretation is that 2000-653A could have spent most of its life in a slightly inclined orbit, that happened to briefly pass through zero inclination in September 1992. Analysis of its orbital plane provides some support for that hypothesis, due to an apparent correlation with the plane of Russia’s GEO satellite constellation.

7.3 Plane Correlates With Russian GEO Constellation at Time of STS 38

At the time of Prowler’s mission, Russia employed modestly inclined orbits for its GEO satellites, initially about 1.5 deg, with RAAN (~273 deg) selected to maintain inclination at or below the initial value for about 3.5 years, sufficient to accommodate their short design life.[18]

Propagating 2000-653A's orbit to the date of STS 38's PKM firings reveals inclination of about 1.6 deg, and RAAN about 269 deg, very close to the initial values of Russian GEO sats, and nearly coplanar with the following satellites, launched about the same time:

SSN	COSPAR	Name	In-Service	Inc	RAAN
20693	1990-061A	Kosmos-2085	1990 Jul 19	1.20	272.1
20923	1990-094A	Gorizont 21	1990 Nov 03	1.42	270.1
20953	1990-102A	Gorizont 22	1990 Nov 23	1.45	271.3
21016	1990-112A	Raduga 26	1990 Dec 20	1.47	274.3
21038	1990-116A	Raduga 1-2	1990 Dec 27	1.52	272.6

This would have enabled Prowler to visit several satellites over their design life, with minimal plane changes to move from one to another. The inclination reached nearly zero in September 1992, but by June 1994, had returned to 1.5 deg. Its mission probably ended soon afterward, certainly by July 1998, when Ed Cannon discovered 2000-653A in its present librating orbit.

7.4 Librating Elliptical Disposal Orbit

Prowler’s stealth mechanism was intended to prevent optical detection when operating within sight of Russian optical space surveillance system, but it would lose its stealthiness upon decommissioning, creating a unique disposal problem, which 2000-653A’s orbit appears to have been designed to address.

By the end of Prowler’s mission, in the early to mid-1990s, it had become fairly common practice to dispose of GEO satellites by manoeuvring them to “graveyard” orbits, several hundred kilometres above synchronous altitude, and many U.S. commercial and military satellites had been disposed of in this manner. For Prowler, this method has the significant drawback of creating an orbit that drifts endlessly around the Earth, regularly passing within sight of Russian territory, which could have resulted in its eventual detection. 2000-653A’s unusual librating elliptical orbit remains over the western hemisphere, out of sight of most of Russia’s territory, while maintaining a reasonable distance from operational geosynchronous satellites, most of the time.

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[18] Nicholas L. Johnson, *The Soviet Year in Space 1990*, Teledyne Brown Engineering, pp. 46-47.

7.4.1 Stays Over Western Hemisphere, Out of Sight of Russia

2000-653A's orbit librates about the western stable point, 105 W, between 73 W and 136 W. Presumably, that longitudinal range was selected on the basis of U.S. knowledge of the location and capability of existing and planned Russian military optical space surveillance sites at the time Prowler was decommissioned.

An early 1990s study of the Russian Space Surveillance System (SSS) reported at least 21 optical or electro-optical facilities at 14 geographic locations in seven countries, that had been part of the USSR: five in Russia, four in Ukraine, and one each in Armenia, Georgia, Kazakhstan, Tajikistan and Turkmenistan. Nine of the sites were at least partly supported by the Russian Academy of Sciences (RAS), which was reported to have "operated additional equipment at sites in Bolivia, Chile, Ecuador, and Egypt."[19]

The study identified four principal sites for positional surveys in GEO, located in Russia, Tajikistan and Ukraine, between longitude 34 E and 69 E, described as "essentially restricted to viewing the geosynchronous ring between 25 W and 120 E," due to their geographical locations.

The study identified one far east Russian site, Yuzhno-Sakhalinsk (~47 N, 143 E), that the NRO probably would have considered a potential detection risk when designing Prowler's disposal orbit. Intensive web searches failed to turn up any information on recent operation of Yuzhno-Sakhalinsk, so it may no longer be in operation, but since it could still have been operational in the mid-1990's, 2000-653A's visibility from that location has been evaluated.

At its probable earliest extreme westerly excursion, in October 1995, when inclined just 2.5 deg, 2000-653A would have remained below the horizon of Yuzhno-Sakhalinsk. At its most recent extreme westerly excursion, in early 2009, then inclined 12.0 deg, it reached 6 deg elevation, which probably would have been marginal, at best, for observation.

The aforementioned three South American sites were in a geographical position to have posed a detection risk to an object in 2000-653A's present orbit; however, they were mentioned only in passing; and among the deficiencies of the SSS listed in the summary of the cited study, was the "invisibility of most of the Western Hemisphere portion of the GEO arc"; therefore, it is doubtful that they contributed significantly to the SSS or to the detection risk for Prowler.

2000-653A's librating orbit appears to be sufficient to keep it out of sight of Russia; however, this otherwise elegant solution has the serious side-effect of unavoidably passing through the altitude of operational satellites, precisely what a disposal orbit is supposed to prevent.

7.4.2 Elliptical Orbit Reduces Time Spent in Operational Zone

The mean altitude of a librating orbit is nearly that of the synchronous altitude, making it a poor choice for satellite disposal. Indeed, it is considered the antithesis of proper disposal; nearly every one of the 145 known satellites in librating orbits were either abandoned there by their owners or died there suddenly, before they could be manoeuvred to the graveyard. The problem is exacerbated by the low eccentricity of typical geosynchronous satellite orbits, which means they never stray far from the most critical altitude region; however, partial mitigation could be achieved by increasing the eccentricity, which appears to have been done with 2000-653A.

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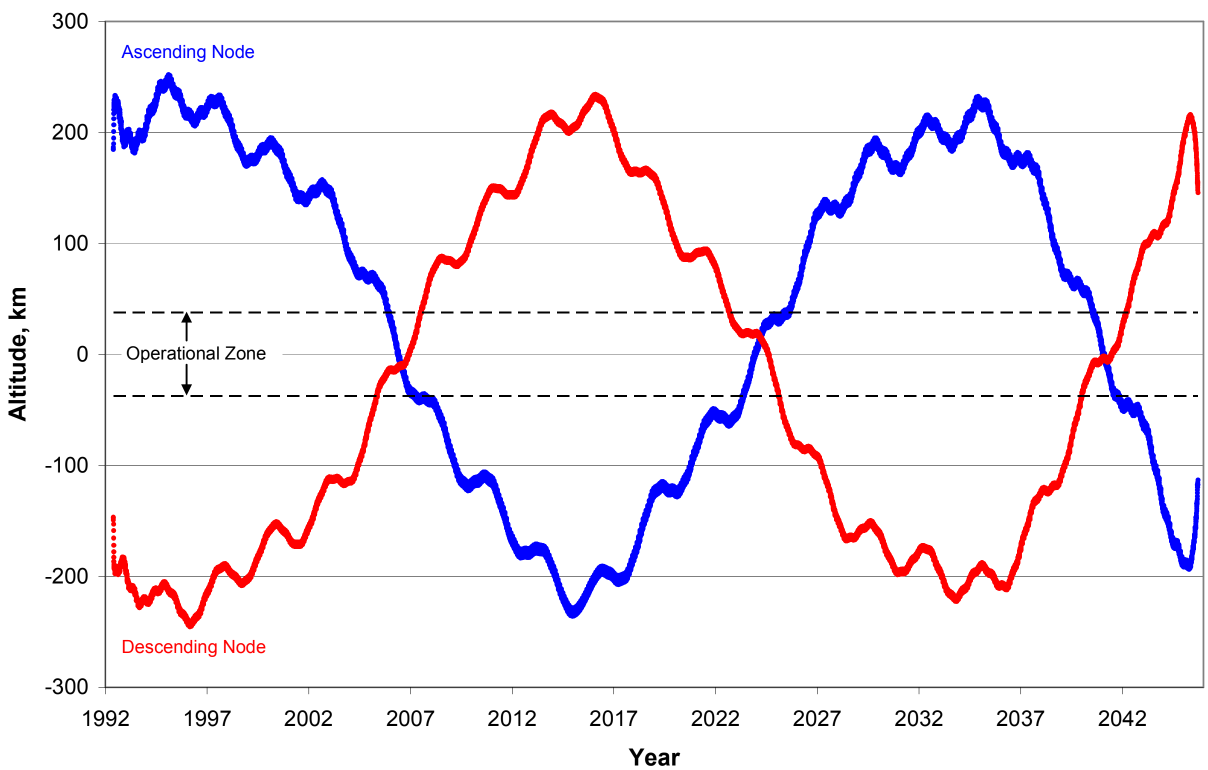
[19] David M. Rodvold and Nicholas L. Johnson (Kaman Sciences Corporation), "The Russian Space Surveillance System: Characteristics and Comparisons with the US SSN," *Proceedings of The 1994 Space Surveillance Workshop, MIT Lincoln Laboratory*.

2000-653A's mean orbital eccentricity of about 0.0047, results in perigee about 200 km *below* synchronous altitude, and apogee 200 km *above*. Although the altitude range falls *entirely within* the 200 km protected zone, it spends a maximum of about 3 hours per day at the altitude of the most critical portion: the *operational zone* within 37.5 km of synchronous altitude, which accommodates station-keeping manoeuvres. (The portion between 37.5 km and 200 km protects spacecraft briefly in drift orbits while enroute to new a location.)

The maximum duration of intrusion into the operational zone occurs when the inclination is near zero, about every 54 years. When the inclination is significantly greater than zero, the intrusions can occur only during the brief node crossings, and only when the argument of perigee is in the vicinity of 90 deg or 270 deg.[20]

Figure 2 shows that over the several decades following its apparent disposal in the mid-1990s, 2000-653A's intrusions into the operational zone would occur only during ~2 year periods about 2006, 2024 and 2041. Intrusions would occur during at least one node crossing on about 13.5% of the revolutions during the 54 years shown, and account for about 1% of the total time, when the duration of a node crossing is defined as the time spent within 3 deg of the node. Retaining the more nearly circular operational orbit would have resulted in intrusions on every revolution, accounting for more than 40% of the total time.

Figure 2: 2000-653A / 90007 - Altitude Relative Synchronous Orbit at Node Crossings



[20] L. Anselmo, C. Pardini, "The end-of-life disposal of the Italian geostationary satellites," *Advances in Space Research 34*, 2004, pp. 1203-1208. Sec. 2 applies this concept to an object in USSTRATCOM's orbit (at the time) for Sirio, with eccentricity similar to 2000-653A, pointing out that, long-term, it is present in the geostationary ring only 0.1% of the time. The authors pointed out that the object's identity was in doubt, and it is now known not to be Sirio (it is unidentified; designated UI.41 by ISON), but the concept is valid, and is applied here to 2000-653A, but with a different definition of geostationary ring.

Fuel economy appears not to have motivated the use of the elliptical orbit, since the delta-V to enter a conventional circular disposal orbit, 200 km above synchronous, would have been nearly identical. Solar radiation pressure increases the orbital eccentricity of objects that have a large area to mass ratio, typically debris, but 2000-653A's orbit appears to be influenced mainly by gravitational perturbations, and its optical characteristics are more consistent with a satellite than debris.

8. Incomplete and Deceptive Cataloguing of Orbited Pieces

The existence of a second satellite launched on STS 38 has never been publicly acknowledged, not even with the usual non-descript serial USA number entry in the public satellite catalogue, nor in the filings of new launches required by U.N. Resolution 1721B (XVI), paragraph 1. Below are the officially acknowledged pieces, along with their actual identity.

COSPAR	SSN	Official Name	Actual Identity
1990-097A	20935	STS-38	STS-38
1990-097B	20963	USA 67	SDS 2-2
1990-097C	20964	USA 67 R/B (1)	SDS 2-2 PKM (Orbus 21S)
1990-097D	20965	USA 67 R/B (2)	Prowler PKM (PAM-D)

The 1990-097B, C and D objects entered USSTRATCOM's (U.S. Strategic Command's) public catalogue sometime between 1990 Nov 26 and 28, at least 9 days after they were deployed, sufficient time for Prowler to have reached its initial GEO location.

USSTRATCOM's catalogue acknowledges a single satellite: USA 67, to which it attributes two rocket bodies, which led to initial speculation by some analysts that it was a large SIGINT satellite, like the Magnum, deployed in 1985 on STS 51C, and in 1989 on STS 33, that employed the two-stage IUS (Inertial Upper Stage) rocket. However, the catalogue clearly identifies the rocket bodies of those earlier launches as IUS, but does not identify the model of those of STS 38. USSTRATCOM's catalogue has not been a model of consistency or accuracy, so this discrepancy might be dismissed, but there is compelling technical evidence that USA 67 could not account for both rocket bodies.

It is generally accepted that USA 67 is SDS 2-2, a second generation NRO communications relay, which employed a single stage perigee-kick motor (PKM) to raise their apogee to a fraction of the operational altitude and then used their integral liquid apogee motor (LAM) to perform all remaining manoeuvres to geosynchronous or Molniya orbit; therefore, it could not have resulted in a second rocket body.

The author's ongoing study of the SDS 2 series (intended to be published when complete), has so far revealed that SDS 2-2 employed an Orbus 21S PKM, with fuel probably off-loaded to 50 percent of maximum, which would have raised the apogee to approximately 11,000 km. The payload-separated mass would have been about 5,900 kg, which the subsequent LAM manoeuvres would have reduced to about 2,560 kg upon entering the initial GEO orbit, similar to that of the HS-389 based Intelsat VI spacecraft, to which SDS 2 is similar.

Since the second rocket body cannot belong to SDS 2-2, it must belong to Prowler, and given the revelation that Prowler's bus is the HS-376, it almost certainly is a PAM-D (Payload Assist Module) in a geosynchronous transfer orbit, as was the case for all fifteen HS-376 communications satellites launched on the shuttle.

Less suspicion might have been aroused had the second rocket body not been catalogued, but only as long as it remained undiscovered, and since it was unlikely to have been stealthy, that could not have been assured. Therefore, cataloguing it may have been the safest option overall. In the event both PKMs were discovered in orbit, the deception might have been aided by their orbits, as approximated below, which could be interpreted as belonging to a two-stage PKM.

Orbit	Inc deg	Perigee km	Apogee km
LEO parking	28.5	270	270
SDS 2-2 PKM	~27.0	270	~11,000
Prowler PKM	~25.0	270	≥36,000

8.1 Proposal to Change Designation from 2000-653A to 1990-097E

Prowler's launch on STS 38 probably will not be acknowledged by USSTRATCOM any time soon, but that does not prevent independent recognition of that fact.

Standard procedure would have been to designate it as the C object, and the two rocket bodies as D and E, but to minimize confusion with the existing official entries, Prowler should be designated 1990-097E. Since that designation is not in the official catalogue, there is no corresponding official catalogue number; therefore, the 90007 hobbyist catalogue number could be retained. The 2-line elements and name line would appear as follows:

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Prowler
1 90007U 90097E   11002.06293503  .00000000  00000-0  00000-0 0    06
2 90007  13.1245  31.7158 0046045 130.0199 230.3936  1.00217850    01
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9. Conclusions

Unknown GEO object 2000-653A / 90007 has two characteristics almost exclusive to satellites:

- a history of flashing to unaided-eye visibility
- a librating orbit

Debris may flash, but seldom, if ever, so brilliantly – a leading observer of flashing GEO satellites could not recall a single case. Debris may be in librating orbits, but accounts for just 1% of known bright objects in such orbits, which are almost exclusively abandoned satellites.

2000-653A has five characteristics consistent with the Prowler story:

- standard magnitude strikingly similar to known HS-376 satellites
- evidence of north-south station-keeping consistent with launch on STS 38
- plane during first years after launch correlates with Russia's operational GEO constellation
- librates over the Western hemisphere, apparently to dispose of it out of sight of Russia
- eccentricity appears to mitigate worst short-comings of a librating disposal orbit

This is strong circumstantial evidence that 2000-653A is Prowler, especially considering that all satellites acknowledged to have been launched to GEO have been accounted for.

Whether 2000-653A is Prowler won't be known with certainty until the latter is declassified, or the former is paid a visit by a future satellite inspector, owned by someone willing to make the findings public. Neither seems likely in the foreseeable future. In the meantime, techniques like photometry and spectroscopy, may be useful in further evaluating the degree of similarity between 2000-653A and known HS-376 satellites.