Planet Earth, Space Debris

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The Astronomy and Space Exploration Society's 6th annual conference in early 2009 discussed the new: new space robots, new space nations, new space motives, and new space problems. That is the general purpose of a conference, after all – to discuss what's new. Included in the discussion was the concept that space flight is becoming more accessible and desirable, and consequently more *risky*. It appears there is a potential situation on the horizon that, at least theoretically, could render future use of Earth's orbit impossible.

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Introduction

FOR THOSE OF US who haven't yet made it up into space to look down onto Earth, there are techniques for tantalizing our temptations: museums, telescopes, websites, simulators, board games, computer games, television shows, radio series, magazine and journal articles, books, movies and even the occasional space conference. And what better for space-enthused individuals like myself to do than sit back and absorb lectures delivered by people that build astronaut tools, plan astronaut missions, or are astronauts themselves?

I was fortunate to stimulate my medial septal nuclei at the Astronomy and Space Exploration Society's 6th annual conference in January 2009. In this opinion piece, I briefly summarize three of the conference's lectures while sharing some small thoughts that rotated, coalesced and concentrated in other systems of my brain that starry Friday night. Finally, I make a case that international efforts to ensure the future safety of Earth's orbit are warranted.

CSA's "Dextreous" Automation

Robotics engineer with the Canadian Space Agency (CSA), Taryn Tomlinson discussed the implementation and future challenges of the agency's newest robotic development, Dextre (see Figure 1). As the latest of at least three major robotic contributions to international space exploration, Dextre adds to the growing legacy of the famous original Canadarm still in use today on NASA's space shuttles. As something of a robot child of both the original Canadarm and Canadarm2 that operates on the International Space Station, Dextre is smaller than and is carried around by his predecessors. Key to its function, Dextre has *two* arms with which to wield tools and cameras fitted onto its 'hands' to allow astronauts (or even an expert down on Earth) to operate Dextre with precision exceeding human vision. Dextre is designed to perform routine

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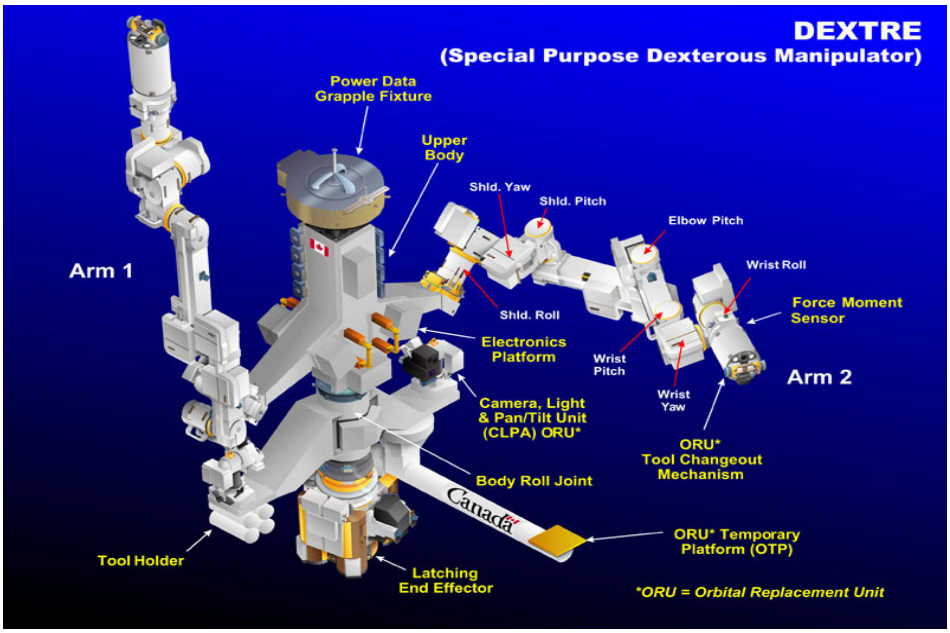

Figure 1 | Dextre, the Canadian Space Agency newest automation. Equipped with tools and cameras, Dextre will be busy conducting maintenance work on the International Space Station's interior. Reproduced with permission from the Canadian Space Agency.

exterior maintenance on the International Space Station previously carried out during chancy and expensive human space walks, thereby enhancing safety while reducing cost.

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Dextre sounds so perfect you probably gather it mustn't have been easy to build. But according to Tomlinson, the greatest challenges when building big space-bound handy-grabbers, like Dextre and the Canadarms, is not in the design or programming, but in finding sufficiently strong materials. This seems odd at first because heavy items should be easy to lift when gravity is negligible as it is on the space station. However, even in microgravity, bodies of large mass are still hard to *maneuver* because they garner large amounts of inertia. Thus, when positioning payloads of 20 tonnes or more, the materials used in these robots (even very strong composites like graphite-epoxy) can wear over time as they are repeatedly twisted and tugged upon. While the CSA probably has a very good idea as to what arm positions are best to optimally distribute the undesirable forces delivered by inertia, higher grade materials are still in demand. The environment of space itself can also be hard on material. Surface temperatures rapidly fluctuate by over a hundred degrees above and below zero and high-speed particles of sizes from smaller than a pea to larger than a pumpkin collide into the robots' Kevlar casing on a continual basis. These menacing particles are known as space debris.

Our Third Nation in Space

In the following talk, Dr. Ying Du, a Senior Spacecraft Systems Engineer at CAST (China Academy of Space Technology), laid out China's previous and future space exploration missions. Du reminded us that five years ago China became the third nation to launch a

human into orbit. This fact has now become common knowledge, but few people may realize that China has since installed a satellite on the Moon, or that China has roughly twice as many personnel employed in their space program than the US does at NASA. From Du's talk, it seems China's short-term plans are similar to those of other space exploring organizations: go to nearby celestial bodies and return with samples. Plant a flag if possible. Du, indeed, indicated an aggressive directive. Oddly, China is not part of the 16 nations conducting research on the International Space Station. I wondered if they were building their own.

Private Space

The speaker most were waiting for that night was Anousheh Ansari - the only person in the room who had defeated Earth's gravitational prison bars and broke for outer space. Ansari exuded an attractive aura, as if radiation experienced in orbit was slowly leaking free. Surprisingly at first to me, Ansari spoke less as an astronaut and more as an entrepreneur. Then I learned she and her family donated a large portion of the money for the original X-Prize (later renamed the "Ansari X-Prize") which in 2004 rewarded 10 million USD to the first private team to ever use a recoverable vehicle to launch the equivalent of three people into space twice in two weeks. The boundary for space was set at the international standard of 100 km. Though an impressive first for the private sector, similar feats were achieved by the US Air Force X-15 when it clipped 100 km twice in the summer of 1963, over four decades earlier. Because 100 km is too low to sustain orbit, this form of "space travel" can more functionally be described as high, fast flight. It does not directly allow for long-term experiments either in the absence of Earth's mighty atmospheric and gravitational forces, or in other regions of the solar system. However, the aim is that the Ansari X-Prize will indirectly give birth to a new era of space travel. This would be akin to how the Orteig Prize directly rewarded a 33.5 hr flight across the Atlantic in 1927, but (some would argue) indirectly gave birth to the airline industry as we see it today. The Ansari X-Prize also succeeded in generating hype and research for single-stage, reusable space-faring vehicles during an era where launches to orbit and beyond employ multi-stage disposable rocket boosters. Hopefully, further development on the new technology will one day achieve orbital altitudes using an entirely reusable (and thus cheaper) system.

Ansari is one of several entrepreneurial spokepersons for the "privatization of space". The so-called "privatization" is not a greedy plan for space to be sectioned, zoned and sold, but rather describes a somewhat novel trend (supported in part by her prize) for companies to project profitable returns on sending people into Earth's orbit and beyond. This concept is relatively new to the human race. Now, for roughly 25 million USD, the richest space cadets (including Ansari in 2006) buy their way into space. The company, Space Adventurers, is even advertising for trips to swing round the Moon for 100 million USD. If your only aim is to visit space (as opposed to explore or colonize), this is all the money you need. If the market is right, privatization of space could potentially do for space travel what it does best for all other industries: ratchet down the cost – something that in turn helps everyone (NASA and CAST included) better afford exploratory expeditions. Of course, there are also other barriers to establishing a modern space-faring species.

The Literal Obstacles

During question period, aspiring space explorers (again, myself included) crowded the microphones for the privilege of tapping into the live expert wisdom. My question was simple: "Does space debris pose a threat to current or future use of space?"

I framed the question by recollecting a slide produced by Ansari that listed potential roles for companies in space. On the list was written something about clearing space debris. While Ansari and Du were lost for words to answer my question, Tomlinson engaged me with this striking comment: "I know our cameras get chipped a lot". How much is a lot? How big are the chips? Could a particle that chips a camera's lens also rip through a space suit? A space plane? Isn't this a challenge needing a solution?

Space debris is all the small pieces of non-functional, human-generated material in Earth's orbit (though this is something of a silly definition since a creative human can find a function for anything and non-human generated particles are just as dangerous as those human-made). Most space debris is comprised of garbage previously pushed out from space stations, retired satellites, rocket cartridges, and collisions between these items. Space debris can remain in orbit for

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decades and generally does so at speeds exceeding 10,000 km/h. Of course, what really matters is the relative speed of impact during collisions. While the accumulating space debris prompted full shielding of the International Space Station, it's probably not feasible to fully shield space suits. Therefore, every space walk is a calculated risk whose odds are growing worse. Odds at orbits further out are even less favourable (see Figure 2). On ac-

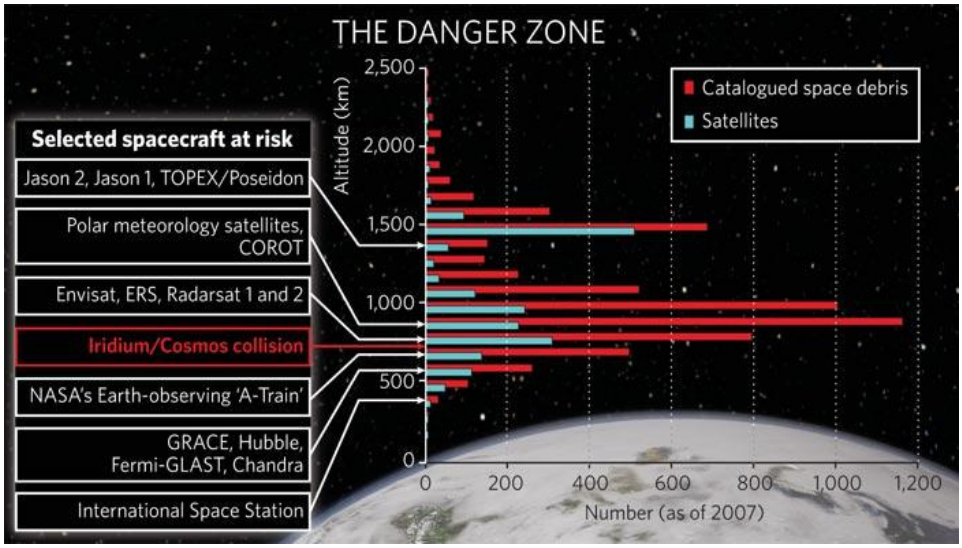

Figure 2 | Levels of space debris as of 2007. Orbits with more space debris have higher risks of impact. Space debris in higher orbits requires the most time to fall back to Earth. Reproduced with permission from G. Forden, Massachusetts Institute of Technology.

count of the space debris problem, NASA has recently considered cancelling their planned repairs and upgrades to the Hubble Space Telescope, one of the most informative and popular tools in astronomy's rich history (1). The importance of a safe near-Earth orbit cannot be overstated. Satellite communication dependent on an intricate array of hundreds of orbiting transmitters and receivers underlies our cell phones, banking systems, military, weather/environment monitoring and forecasting, and more. Plus, our view of the universe, as in the case of Hubble and a collection of other telescopic satellites and sensing probes, requires a safe near-Earth orbit. All these technologies are of immediate importance. But perhaps even more critical than the use of Earth's orbit to allow us to operate as we do on Earth today, is the use of Earth's orbit to allow us to operate as we will have to *off* Earth tomorrow. For it is well accepted that sooner or later the cosmos will absolutely force us to do just that.

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When I asked my question, some present may have assumed it was meant to alarm. In truth, I was innocently curious. Then on February 11th, just 2 weeks after the conference, a deactivated Russian satellite (Cosmos) and an active US satellite (Iridium) collided (1). This single mishap may have created the most dangerous amount of space debris since China proved the accuracy of their rocket technologies by shattering one of their own orbiting satellites in 2007 (2). These events are not all that rare; also in 2007, an *active* Russian rocket booster – silently orbiting for two years following a failed satellite launch – suddenly exploded (3). Fortunately, this explosion was in a very low orbit and most of the debris crashed back into Earth within the following couple months, making the brilliant show left behind for those underneath an equally notable consequence. Then on March 12th, while this opinion piece was still in press, astronauts aboard the International Space Station took refuge in an escape capsule due to a close encounter with space debris that could have damaged the station's life support systems (4). Even more recently, on a rendezvous to the Station, the space shuttle itself came into contact with space debris (5). Thankfully, no lives were lost.

Yet the point is obvious. As more collisions, explosions and mishaps occur – an inevitability with the increasing orbital presence exercised by existing space nations, emerging space nations and the private space sector – the more debris is created. And, in accordance with statistics, the more debris is created, the more collisions occur. This feedback loop could eventually result in something know as *Kessler Syndrome*, the situation where debris in Earth's orbit is so abundant that space exploration and satellite

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technology becomes entirely impossible (6).

The size of the "danger zone" is expanding. Now, at the early stages, we seem to have an opportunity to implement methods that can stop or curb the proliferation of space debris in the future.

Planet Earth, Space

During the conference's humble discussion on the dawn of a "Global Space Age," the International Space Station inaudibly floated overhead roughly ten times. From the nature of the talks, it became completely lucid that space exploration is alive and thrusting forward. These space people are of no small imagination and I have complete faith they will overcome the obstacles, literal or otherwise, to pursue their profession. We depend on it. On the walk home I did a lot of gazing upward. Space debris or not, it's certainly a nice place to peek up at the sky, Planet Earth, Space.

Websites to explore:

Dextre: *http://www.asc-csa.gc.ca/eng/missions/sts-123/default.asp*

China's space program: *http://www.cnsa.gov.cn/n615709/cindex.html*

Space Adventurers: *http://www.spaceadventures.com*

Space Security Index: *http://www.spacesecurity.org/*

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