De-Orbit Services

Executive Summary

ST12-DID4-V1-003

July 2010

SpaceTech
MASTERING **SPACE SYSTEMS**

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Securing Access to Space and Protecting Space Assets from the Threat of Orbital Debris

Orbital debris is a clear and present danger to spacecraft. Since the dawn of the space age, each space mission has left debris in the Earth's orbit. Initially this debris was thought to be insignificant when contrasted against the vastness of space itself. However, debris left in orbit will remain for decades and with every passing year more missions are launched. Collisions with debris are on the rise and today the leading researchers predict that orbital debris, if left unchecked, will render useful orbits inaccessible in the future. This conclusion is unavoidable even if all future launches were to be halted completely.

The only recognized solution is to actively begin removing orbital debris. International space agencies and organizations across the world are finally beginning to acknowledge this problem, and momentum is now quickly building towards finding – and funding – a solution. RetroSpace offers an early and cost effective solution.

Using advanced robotic spacecraft, the RetroSpace system will identify and remove the most hazardous orbital debris to stabilize and then improve the orbital debris environment. The RetroSpace system maximizes the use of existing and tested technologies such that the mission is able to be realized in a responsive timeframe. Coordinating with international partners and operating within existing legal and regulatory frameworks, RetroSpace provides a commercially viable solution to the orbital debris threat.

RetroSpace Proposal Contents

Volume 1	Executive Summary	ST12-DID4-V1
Volume 2	Technical Proposal	ST12-DID4-V2
Volume 3	Management Proposal	ST12-DID4-V3
Volume 4	Appendix A: System Engineering Package	ST12-DID4-V4
Volume 5	Appendix B: Financial Spreadsheet	ST12-DID4-V5

Executive Summary Contents

This executive summary covers the following subject areas:

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Overview

The Problem

Space is an invaluable resource to the world. Satellites provide unique opportunities to mankind for services that improve our quality of life and space assets have developed to the point that they are vital to the global economy.

Satellites - and the critical services they provide - are under increasing threat.

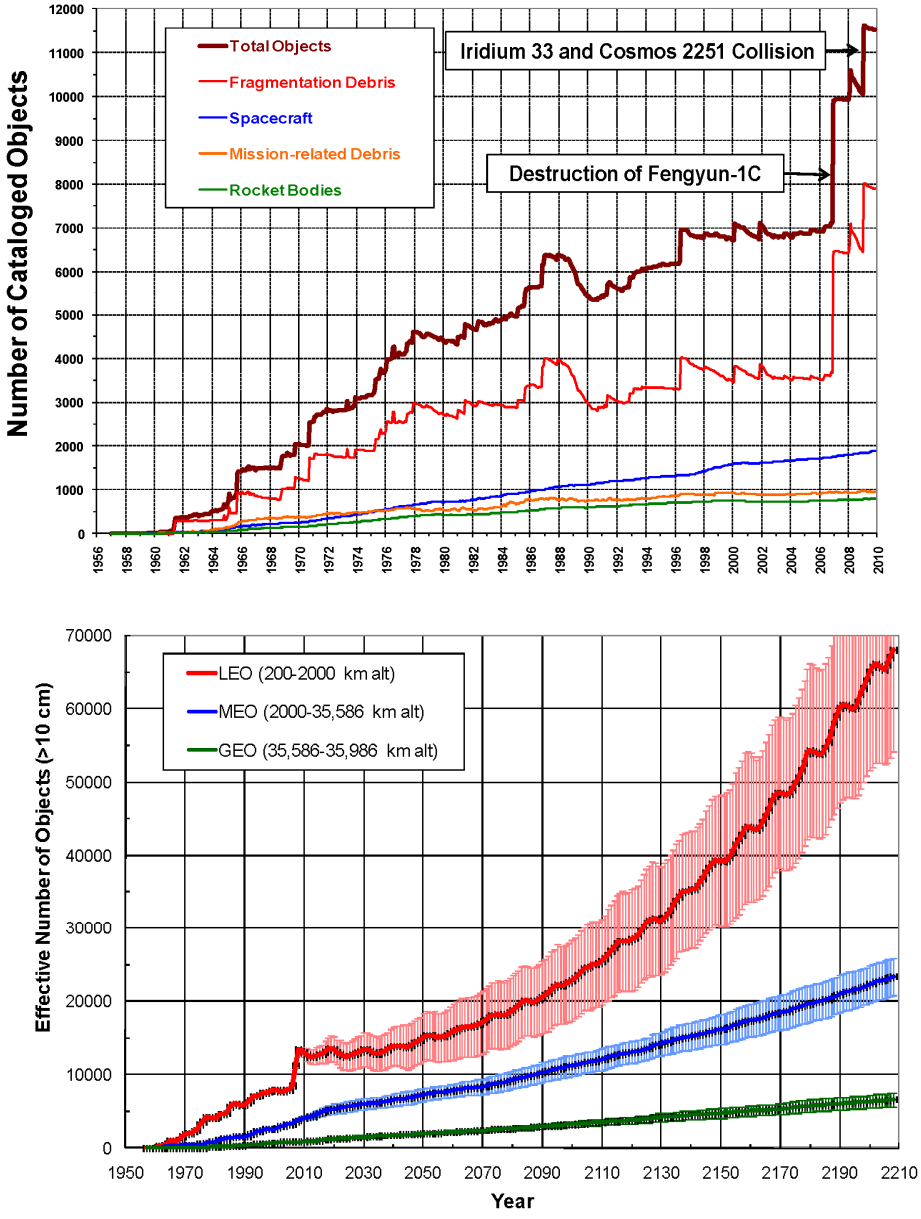
Since the beginning of the space age, each space mission has left debris behind in the Earth's orbit. Once left in orbit, this debris remains for many decades. Collisions with orbital debris render operational spacecraft useless and this in turn creates more debris. Debris in space has reached a critical mass, and collision events are becoming more frequent, as shown in the following table:

Year	*Event*	*Result*
1991	Inactive Cosmos 1934 satellite hit by cataloged debris from Cosmos 296 satellite	Increased debris
1996	Active French Cerise satellite hit by cataloged debris from Ariane rocket stage	**Asset destroyed!**
1997	Inactive NOAA 7 satellite hit by uncataloged debris	Increased debris
2002	Inactive Cosmos 539 satellite hit by uncataloged debris	Increased debris
2005	US Rocket body hit by cataloged debris from Chinese rocket stage	Increased debris
2007	Active Meteosat 8 satellite hit by uncataloged debris	**Outage in service**
2007	Inactive NASA UARS satellite believed hit by uncataloged debris	Increased debris
2009	Active IRIDIUM satellite hit by inactive Cosmos 2251	**Asset destroyed!**

Source: compiled by Dr. David Wright [Union of Concerned Scientists]

Collisions of two large spacecraft, such as the 2009 Cosmos-Iridium incident, are thankfully rare. However, collisions with smaller fragments are frequent and can be just as catastrophic. Many of these fragments are too small to be adequately tracked for avoidance.

Adding fuel to the fire, each year there are further launches into space and global systems become more dependent on satellite services. The amount of debris is on the rise, as are the chances for catastrophic collisions. The amount of orbital debris has roughly doubled in the last decade, and continues to rise at an alarming rate, as shown in the following figures:



Source: Debra Shoots, NASA Orbital Debris Program Office, May 2010

The most recent research shows that space debris, if left unchecked, will destroy more satellites resulting in more debris that in turn destroys even more satellites. This soon results in a self-sustaining cascade scenario (also referred to as the "Kessler Syndrome") that will envelope the Earth in a dense cloud of lethal fragments, rendering certain orbits useless and posing the risk of blocking access to space entirely. The above figure illustrates this exponential debris growth expected in Low Earth Orbit (LEO).

The future is bleak. Action must be taken.
The time to act is now.

The Opportunity

Research suggests that this cascade scenario can only be avoided by active removal of large debris from the most congested orbits. Current estimates are that ten to fifteen large objects per year must be removed, representing a total average mass of approximately 6 tons (*reference: Proceedings of 1st European Workshop on Active Debris Removal, Paris, June 2010*). This activity must begin sooner rather than later.

Recent events (notably the Cosmos-Iridium collision, and the destruction of Fengyun-1C) have focused international attention on the problem of space debris. National and international space agencies across the world have acknowledged the magnitude of the orbital debris threat and momentum is finally building to find, and fund, a solution.

While some promising technologies have been proposed already, no one has been able to address the problem with an end-to-end solution that is ready to implement and satisfies all international parties.

The need exists. Awareness is increasing.
There is no comprehensive solution at present.

The Solution

The RetroSpace vision is a profitable, end-to-end system for active debris removal. The RetroSpace system will remove fifteen large debris objects per year, in a safe manner and with the consent of the debris owner.

RetroSpace is a privately owned company formed to tackle the specific mission of cleaning space debris from Earth orbit. RetroSpace is the only company to offer a solution that combines:

- Affordability to the customers
- Profitability to the investors
- Proven technologies that enable a responsive solution

RetroSpace will provide a necessary public service at a minimal cost to world governments, whilst simultaneously creating significant returns for all stakeholders.

RetroSpace is a profitable end-to-end system that will actively remove fifteen large debris objects per year.

Business Summary

Initial funding for RetroSpace will come from the company founders and venture capitalists. This initial funding will allow RetroSpace to begin intensive lobbying efforts to ensure that necessary frameworks are put into place for the future business success. This funding will also allow key aspects of the technical solution to be developed.

In 2012, RetroSpace will secure a strategic partnership with a satellite manufacturer for additional financing needs. This manufacturer will not simply be investing in RetroSpace, but also ensuring a manufacturing contract to build multiple spacecraft, securing a steady stream of revenues for the manufacturing business.

In 2013, RetroSpace lobbying efforts will secure $300 million through a government-backed public bond. The “Clean Skies Bond”, issued by a major international financial institution, is a synergistic financing vehicle as it allows the government to support a public service by providing a guarantee, rather than providing funds directly.

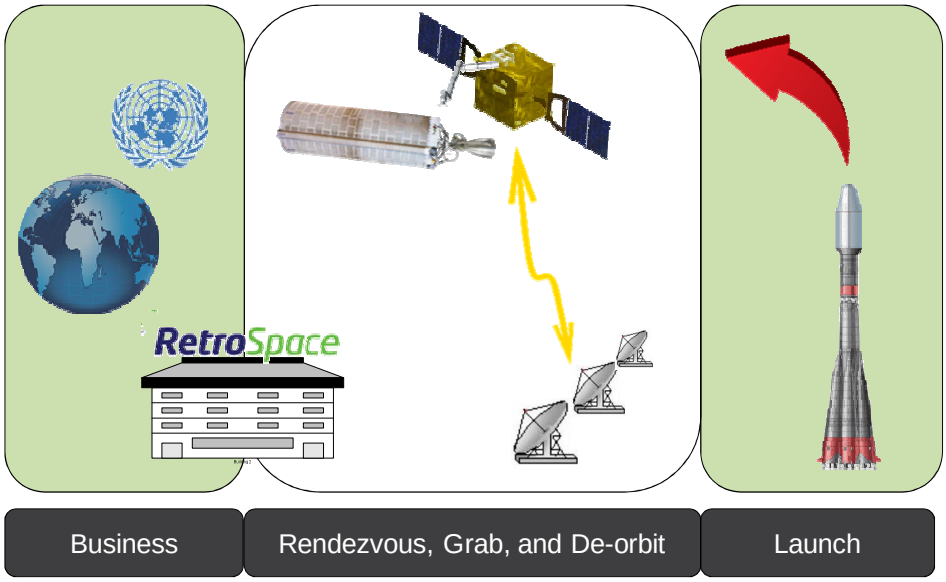
RetroSpace lobbying will also create the “flagship” customer for our debris removal service, required in 2016. The international Space Debris Removal Fund (SDRF), subsidized by governments and administered by an international party, will be created to pay fees for the removal of space debris. RetroSpace is positioned to win the competition to secure exclusive rights to act as the provider of this service.

Once RetroSpace has a full fleet of operational spacecraft (dubbed “*RetroSats*”) and is serving the SDRF need at full capacity, RetroSpace will begin to exploit additional, fully commercial, revenue streams.

Functional Architecture

The RetroSpace system can be split into three segments: the space segment, the launch segment, and the ground segment.

The launch segment lifts RetroSat into the required orbits. Business management, mission planning, and spacecraft operations are performed and managed through the ground segment.

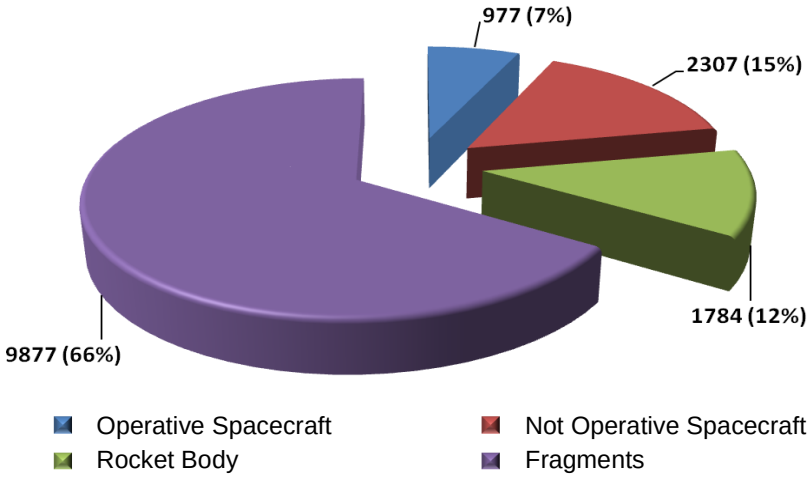


The space segment is comprised of a fleet of several RetroSat spacecraft, each equipped with a robotic arm. These RetroSats rendezvous with debris and then grab the debris with the arm. The RetroSat then thrusts to a lower altitude, tugging the debris down with it. At a suitably low altitude, the debris is released by RetroSat and the Earth’s atmosphere then exerts enough drag to naturally pull the debris back to Earth. The debris will burn up in the upper atmosphere. After releasing the debris, RetroSat then moves up to the next piece of debris. A fleet of seven RetroSats is able to remove an average of 18 pieces of debris per year.

Market

Debris Trends

The current trackable population of space objects consists of more than 15,000 catalogued items. These objects include operative and not operative spacecraft, rocket bodies, and fragments. Only a small fraction of these objects are useful satellites, the rest is debris (see pie chart below). Additionally, there are tens of thousands of additional smaller debris fragments that are untrackable.

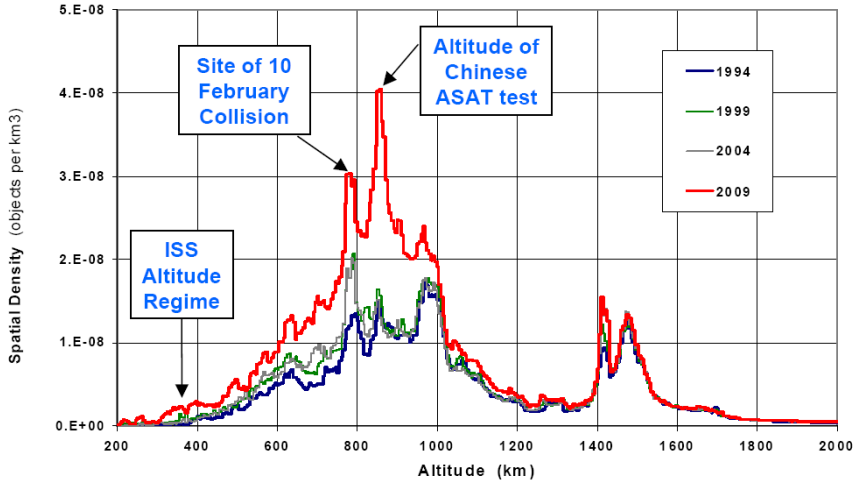


Source: ESA Debris Office Database

Most of this debris is concentrated in the lower Earth orbits (LEO), between 600 and 1200 km in altitude. Three such orbital regions have been identified as the most critical due to the high congestion of mass. These regions pose the highest collision risks and this is where the cascading failure effect, referred to as the Kessler syndrome, is most feared. The LEO regions most affected are:

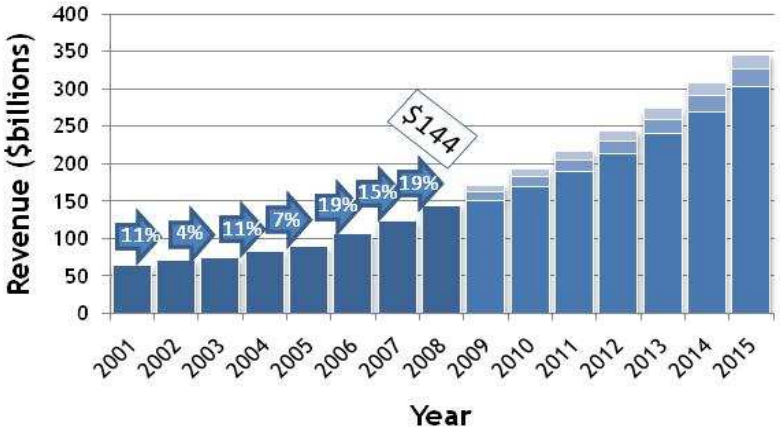
a) altitude = 1,000 km ± 100 km at i = 82°± 1°
b) altitude = 800 km ± 100 km at i = 99°± 1° ← Sun Synchronous
c) altitude = 850 km ± 100 km at i = 71°± 1°

The relative density of debris at LEO is illustrated in the following figure, where the highly congested regions identified above can be clearly seen:



Source: Marshall Kaplan Space 2009

Activity in space is on the rise. Launch rates have been trending upwards for many years, and this will add to the congestion of orbits. At the same time, the criticality of space assets is increasing across all sectors. Space assets are becoming more deeply embedded into civilian, military and commercial systems world-wide. Using commercial revenues as a yardstick, space assets have tended to roughly double every five years as illustrated below:

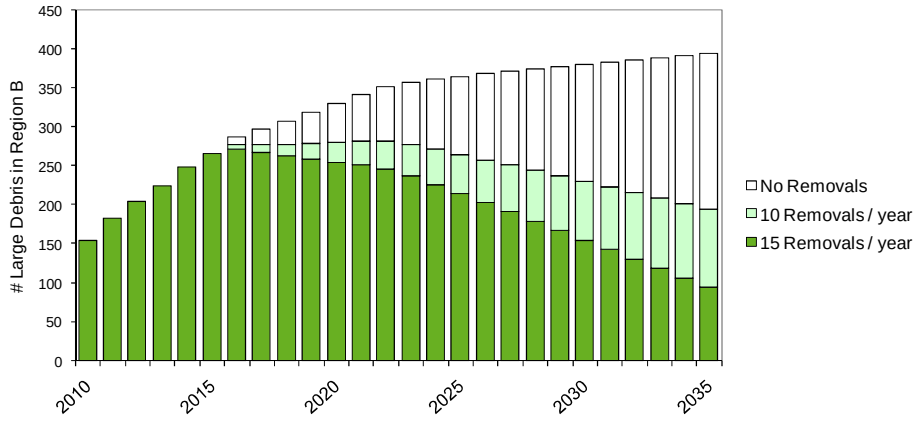


Source: State of Satellite Industry Report, SIA 2009

Market Scope

As activity in space increases, so does the debris. The potential market is considerable. RetroSpace estimates the market for debris removal market is worth more than $200 million per year.

The market for large objects is not only significant, but also stable. Based on conservative estimates for future launches into LEO, and the optimistic assumption that 95% of these will be successful in implementing some form of the suggested debris mitigation recommendations, there is still a sustainable market for RetroSpace services well into the future.



The figure above illustrates that RetroSpace debris removal will stabilize the current situation, maintain that stabilization in the face of increasing activity, and then act to improve the situation into the future.

Products and Services

The RetroSpace system offers the following products and services:

- **Debris Removal** of uncontrolled and intact debris:

The primary revenue stream for RetroSpace is the debris removal service. RetroSpace will remove large objects from the most congested orbits on behalf of the SDRF. This will begin in LEO, but it is envisioned that the RetroSat platform could be used in the future for GEO applications to serve commercial clients.

- Direct sales of the **RetroSat** platform and it's unique capabilities:

RetroSpace is cognizant of the fact that not all actors in space will want their assets inspected closely and manipulated by a third party. For that debris which is not addressable by RetroSpace, the company intends to sell and license the full RetroSat platform to friendly entities.

- **"Space Tug"** services to functional satellites:

As a logical extension of removal, RetroSpace can also offer "Space Tug" services. RetroSat is able to mate with a client spacecraft and provide the thrust necessary for altitude adjustments or inclination changes. One possible application is mission recovery of satellites that are stranded in the wrong orbit through a launcher error.

- **Damage Inspection** services to orbiting satellites:

RetroSat is endowed with an advanced vision system for surveying debris during proximity operations. In the same way that it surveys debris to determine spin rates and potential grapple points, RetroSat is able to inspect client satellites remotely to assist in failure investigations.

Customers

In the cluttered LEO orbits, the public sector has an intense interest in debris removal, and securing future access to space. Many of the satellites in LEO are owned by governments and public organizations. Extensive surveys and customer interviews conducted by RetroSpace have made it clear that commercial entities are not willing to pay for debris removal themselves. Thus, the public sector is the targeted customer at LEO. Additionally, space-faring nations have an obligation to resolve the LEO debris problem to clean up space for greater public good. A relative distribution of "debris owners" can be seen in the following table:

SATELLITE BOX SCORE
(as of 01 January 2009, as cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	78	2695	2773
CIS	1379	3036	4415
ESA	38	36	74
FRANCE	49	331	380
INDIA	36	111	147
JAPAN	105	69	174
US	1098	3161	4259
OTHER	425	96	521
TOTAL	3208	9535	12743

Source: The Orbital Debris Quarterly News, Vol. 13, Issue 1 January 2009

Future business expansion will cover extended services beyond space debris removal. In contrast to LEO, commercial operators are interested in debris removal at GEO as that is where the high revenue commercial satellites reside. Nonoperational satellites blocking valuable GEO slots are excellent candidates for the RetroSpace "space tug" service which can tug these dead satellites to a GEO graveyard orbit.

Other customers for RetroSpace may include launch service providers, who have an obligation to de-orbit their upper stages, and the insurance industry may eventually be interested in our capabilities for failure investigations and mission recovery operations.

Market Creation

At present there is no established market for debris removal services. There is a clear need but no precedent solution, and the framework for addressing this market is unclear. RetroSpace intends to create the market for debris removal. This will be achieved through persistent and intense:

- Rallying of the space agencies to maintain the current momentum, raise further awareness, and gain their direct support of our solution
- Lobbying of the international organizations such as the United Nations Office for Outer Space Affairs and the Committee on the Peaceful Uses of Outer Space (COPUOS) to ensure that an umbrella organization is able to stimulate a coordinated response amongst nations

These lobbying efforts are aimed at the specific creation of:

- A global fund, administered by an appropriate international body that is to pay for the cleanup of orbital debris.
- Alignment of key governments to provide a guarantee for a public bond vehicle to support the development and early deployments of RetroSpace.

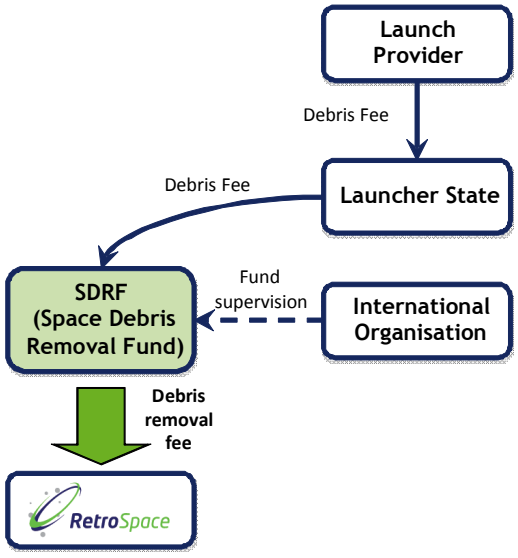
RetroSpace is uniquely positioned to win the competition to secure exclusive rights to act as the service provider to the global fund by being first to market, and having cultivated relationships with key decision makers.

Space Debris Removal Fund

Within the international arena, RetroSpace will lobby for the creation of an international fund for space debris removal. RetroSpace will promote the creation of a Space Debris Removal Fund (SDRF), administered by an international body (such as COPUOS), and financed by a levy on future launches into space and partially subsidized with government contributions.

Contributions to the fund are forecast to be just $100-200 million per year, shared by all of the world's space agencies. To put that figure into context, this represents less than 1% of annual public space budgets, worldwide. If governments wish to reduce their contributions, RetroSpace envisions that the fund could be subsidized commercially through a nominal levy on all future launches.

International governments and organizations must agree and set up this specific space debris removal fund and mandate any corresponding fees that might be raised at launch through the launch service provider. With an average levy totaling only 2% of a typical launch cost, this is not expected to be a negative stimulus to the launcher industry. Even at this low rate, such a levy is expected to generate approximately $50 million per year for the fund.



Our extensive lobbying efforts and system design iterations will uniquely place RetroSpace at the forefront of tapping the SDRF monies. RetroSpace expects to gain the right to act as the exclusive service supplier for the SDRF administrators.

System description

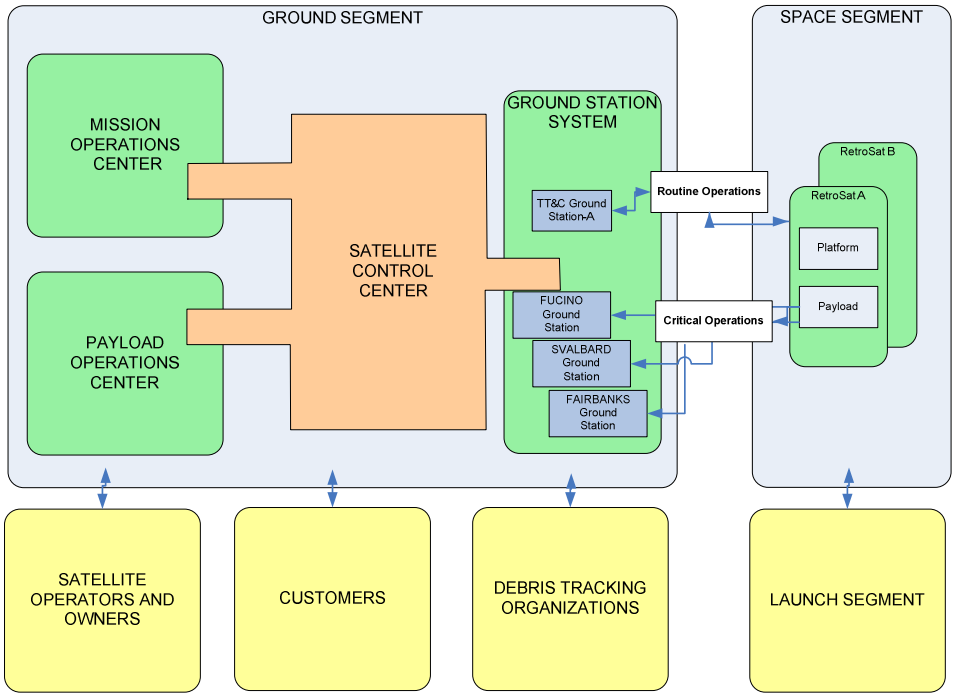
System Architecture

The RetroSpace system consists of the following integrated segments:

- **Space Segment**
  A fleet of identical satellites placed in the low earth orbit region of interest. Each RetroSat is equipped with a robotic arm and a vision system. These systems enable capture and control of debris under manual ground control.

- **Launch Segment**
  A flexible launch strategy has been chosen. The current baseline supports either a clustered launch with two or three RetroSats or dedicated single launches.

- **Ground Segment**, comprising of various centers located worldwide:
  - Mission and Payload Operation Centers (MOC-POC), in charge of mission planning, management and payload operations;
  - Satellite Control Centre (SCC), in charge of satellite command and control, including communications;
  - Ground Station System (GSS); providing connection to both the spacecraft and the payload.



The figure above illustrates the system segments and lists external system interfaces. A key interface will be with debris tracking organizations. The RetroSpace system will obtain debris information such as updated orbital elements, attitude, end-of-life mass, size and shape from existing debris catalogues and databases. Possible providers of this kind of data are the Space Surveillance Network, ESA's Space Situational Awareness division and select other commercial providers (e.g. Center for Space Standards & Innovation).

Space Segment

Once launched, the RetroSat executes the following mission phases:

1. Cruise to the orbit of the selected debris
2. Rendezvous with the selected debris
3. Capture the debris using a robotic arm
4. Stabilize and analyze the newly formed combination, and prepare for de-orbit
5. Cruise to the disposal orbit
6. Release the debris
7. Raise orbit again, and repeat.

These phases are repeated until the end of its 7 year design life, at which point the RetroSat de-orbits itself together with the last debris. The concept takes advantage of the different precession rates of the disposal orbit with respect to that of the next debris, in order to reduce the propellant needed to perform the orbit change necessary to move to next debris. After releasing a debris, the RetroSat waits in the disposal orbit for the optimal window for initiating thrust is achieved (propellant usage can be reduced by exploiting certain orbital dynamics in our favor).

Each spacecraft is capable of de-orbiting 2-3 pieces of debris per year, on average. In order to meet the objective of 15 objects per year, a fleet of RetroSpace spacecraft will be deployed in parallel.

RetroSat Platform

The RetroSat subsystems design is based on flight proven technology in the effort to minimize the development risk and the cost. RetroSat is a 3-axis stabilized spacecraft employing an advanced rendezvous and capturing system as payload. This payload does not require particularly precise pointing. The capturing of the debris does not require the RetroSat to spin, simplifying the spacecraft configuration.

RetroSat uses a set of five electrical propulsion ion engines for thrust. These thrusters are aligned in the velocity direction during the cruise stage and aligned in the anti-velocity direction when de-orbiting the debris to lower the orbit altitude. This requires the RetroSat to be able to rotate about the yaw axis.

RetroSat employs deployable solar panels that rotate to allow for flexible energy capture in multiple orientations. A maneuver is executed at the designated release orbit to orient the composite so that the debris is in the nadir direction.

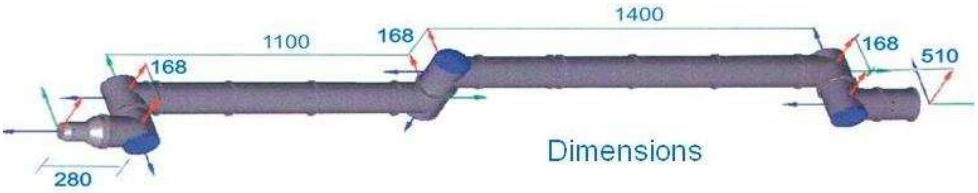
The externally mounted instruments will be located on the X panel. The Y panels will be used to accommodate the solar arrays in the stowed position. The robotic arm will be located on the corner of the Z panel.

Payload Operations

RetroSat has a rendezvous sensor suite to identify, track, and approach space debris. Information from ground based tracking networks and on-board GPS is used for orbit phasing to within 5km. At this point the debris is acquired directly by RetroSat through various sensors to enable relative navigation. As RetroSat approaches the debris, higher resolution sensors take over, as listed in the following table. The majority of rendezvous operations are performed autonomously.

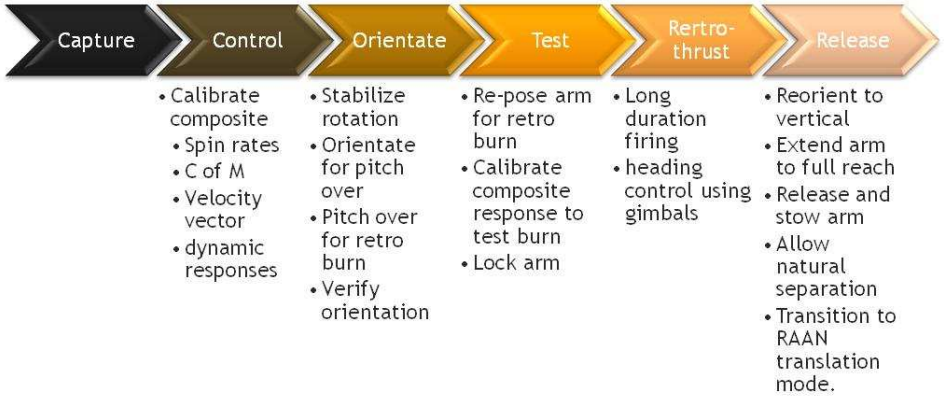
Stage	Function	Required Debris Details	Sensors	Range
Phasing	Matching of orbits	Two-Line Element sets	GPS	> 5 km
Far Range	Detection, tracking	Bearing, range, range rate	Far-range camera, mid-range camera, IR sensor	5 km to 200 m
Close Range	Inspection, final approach	Physical properties, attitude in all 6 degrees of freedom	LiDAR, mid-range camera	< 200 m

Capture of the debris is performed using a robotic arm. The arm selected by RetroSpace has been developed by the German Aerospace Center. This arm is derived from the successful “ROKVISS” experiment, has been qualification tested and is due to be flight demonstrated on the upcoming “DEOS” program.



Source: DLR

RetroSat and the captured debris form a new, composite, satellite. RetroSat then performs minor maneuvers to establish a new control authority before locking the arm in place and initiating the de-orbit thrust.



Ground Segment

The ground segment:

- provides sufficient ground station contact time to download the data generated
- guarantees 15 to 20 minutes of continuous communications between the satellite and ground operators to support the capturing phase
- ensures that the round trip data latency is compatible with robotic operational requirements

RetroSpace's ground segment baseline consists of one ground station for nominal TT&C operations. A single ground station will provide more than one ground contact per day which is sufficient to download the typical housekeeping data generated during one day.

Robotic operations, however, are critical and will require trained personnel and more frequent and persistent contact times. Instead of building a dedicated system, RetroSpace intends to lease existing ground support networks to supply part of the elements needed. In fact, a number of commercial or agency ground systems can handle different missions and are available to support user missions.

A leasing strategy has been adopted for the considered ground segment elements except for the Payload operations and data system (POC). In this frame a user terminal for robotics operation (including the robotic arms and the docking mechanism) is specifically developed and operated by RetroSpace staff.

Launch Segment

Concerning the launcher selection, a flexible launch strategy is envisaged. The final launcher(s) will be selected in a later stage.

- Clustered launches of 2 RetroSats, combined with
- Dedicated single launches

Launch Strategy	Baseline	Alternatives
Single	LM-4B	LM-2C GSLV
Dual	Soyuz	Proton LM-2E

Single **Dual**

LM-4B **Soyuz**

Design & Development Plan

In accordance with established industry practices, the life cycle of the RetroSpace technical design is divided into the following 6 phases:

Phase A: Feasibility Analysis, completed 2010

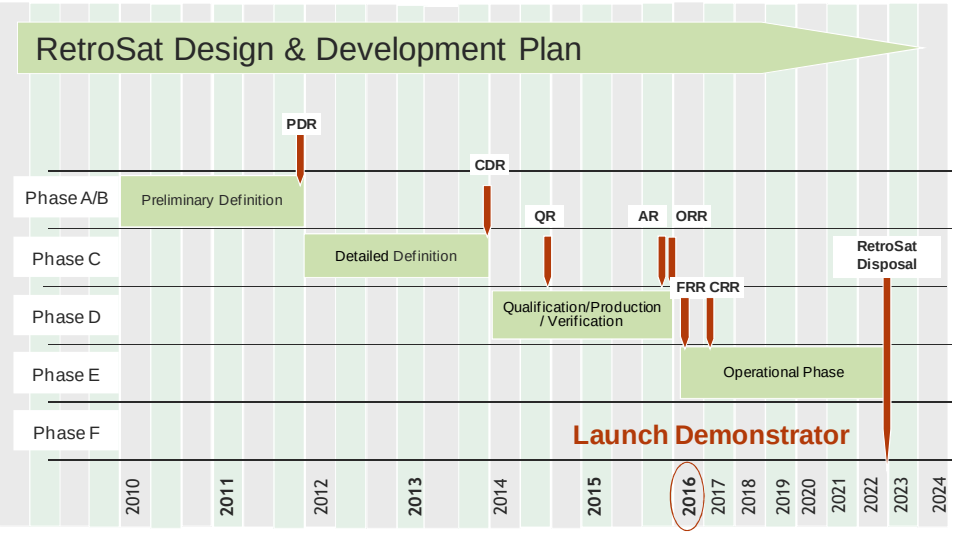
Phase B: Preliminary Definition, to be completed 2012

Phase C: Detailed Definition, to be completed 2013

Phase D: Qualification and Production, beginning 2014, first launch 2016

Phase E: Operations, beginning 2016

Phase F: Disposal, planned end 2022 for the first RetroSat



Legal and Regulatory

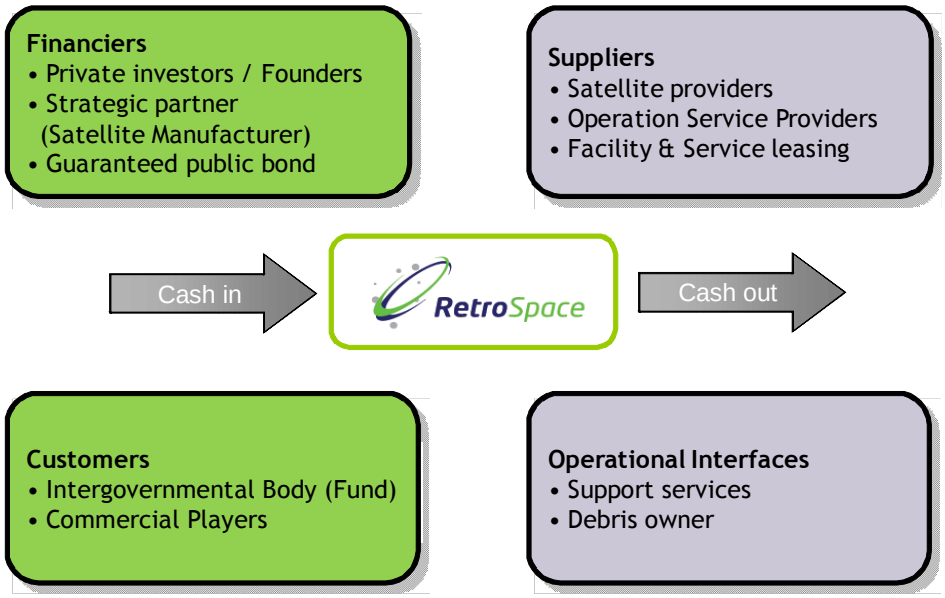
Based on the various treaties stipulating that control and jurisdiction over space objects remains with the owner, and that liability remains with the original launching state, there are no legal prohibitions against space debris removal operations with cooperative states and debris owners.

To be compliant with existing law, RetroSpace will only remove debris with the express consent of debris owners and launching states, comply with the debris mitigation guidelines of the Inter-Agency Space Debris Coordination Committee (IADC), avoid weapon technologies, and maintain a fully transparent and accountable operation.

Business Implementation

Business Context

Providing an end-to-end service for the removal of space debris implies that a number of interfaces must be established. From a business point of view, these key interfaces can be grouped at a high level into cash-contributing or cash-absorbing entities. Those contributing cash to RetroSpace include investors, financiers and of course customers. Those absorbing cash include suppliers of key facilities, equipment and services.



NextGen PPP

The proposed business context of RetroSpace forms a Public-Private-Partnership (PPP) which goes beyond the typical setup consisting of one national government and one industrial partner. The PPP of the next generation ("NextGen PPP") reflects an extended structure matching the global nature of the space debris problem addressed by RetroSpace. This "NextGen PPP" is characterized by the following parties:

- Private Investors
- Private Industry
- Multiple Governments
- International Organizations
- General Public

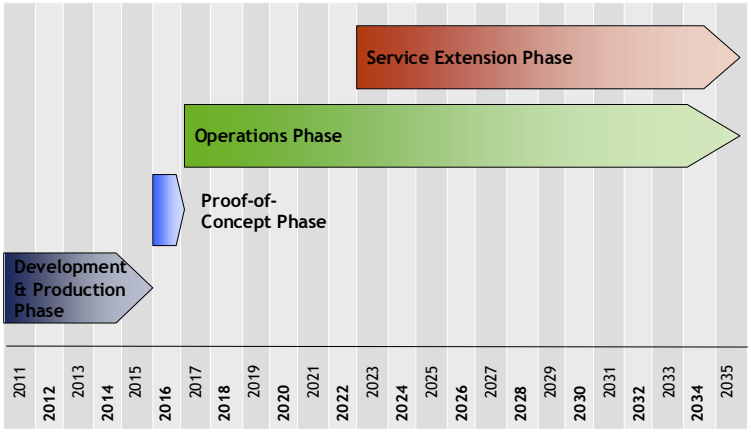
This setup is used to provide a public service which exhibits commercial efficiency. Using a lifecycle based approach each individual partner's capabilities and strengths are exploited in appropriate project phases. Consequently, a balanced risk-reward ratio for all partners is achieved.

	Role	Objective	Timeframe	Means
Founders	• Entrepreneur	• Vision	2011 -	• RetroSpace Concept • Culture
Financial Investor	• Early-stage value-add	• Short-term return	2012 - 2017	• $20 M Equity
Strategic Investor	• Key mission capabilities • Funding	• Long-term business & return	2012 - 2035	• $70 M Equity • Satellite Production
Governments	• Customer • International coordination • Funding & Support	• Debris removal • Economic stimulation	2013 - 2035	• SDRF Setup • Clean Skies Bond guarantee • SDRF Contribution
General Public	• Funding	• Return • Sustainable space	2013 - 2035	• Clean Skies Bond purchase

Phased Approach

In order to set-up the business, a phased approach in building the commercial and technical solutions is considered. This process is divided into the following major phases:

- Development & Production Phase
- Proof-of-Concept Phase
- Full Deployment and Operations Phase
- Service Extension Phase



The initial phase is the Development & Production Phase. During this period, RetroSpace will secure key technologies, complete the end-to-end system design, find a manufacturing partner and lobby agencies to ensure the necessary funding is put into place (namely the SDRF and “Clean Skies Bond”). This phase ends with the launch of the first RetroSat and the Proof-of-Concept Phase begins. During the first year of operations, RetroSat-1 will demonstrate the full capabilities of the RetroSpace system to retire any remaining operational risks.

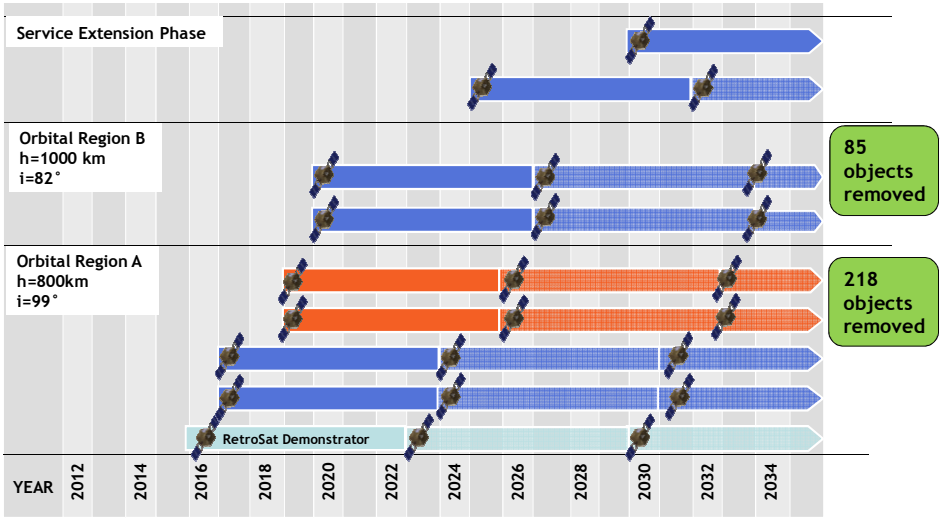
With a successful first spacecraft, RetroSpace will quickly begin full fleet deployment during the Operations Phase to provide the debris removal service. In 2020 RetroSpace will be fully operational with seven spacecraft to meet the primary needs of a debris removal service. At this point, RetroSpace will look to develop additional revenue streams and continue growth during the Service Extension Phase

Fleet Deployment

The deployment schedule is characterized by the objective to achieve a high debris removal rate as early as possible to maximize the early revenues. At the same time, a flexible deployment scheme into the various orbital regimes of interest needs to be considered. This has led to an approach mixing single and dual launches.

The requested production phase allows the manufacturer to implement synergies in the production cycle with a correspondingly reduced cost of the satellites.

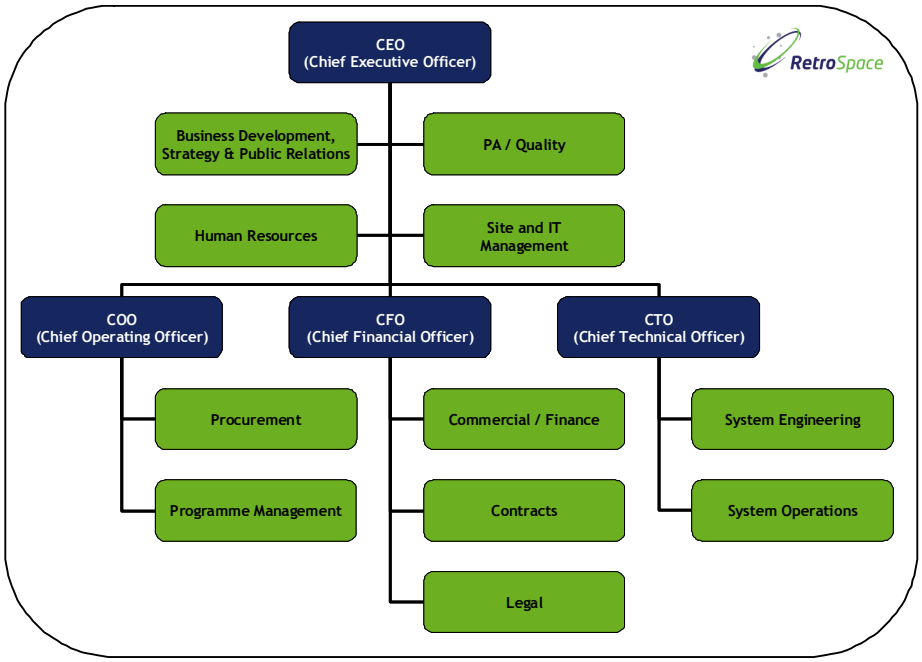
Once a satellite has reached its design lifetime, it will be replaced by another satellite, thus maintaining a constant number of satellites in operation after full deployment. Additional RetroSats can be launched at any time to accommodate unforeseen increases in demand.



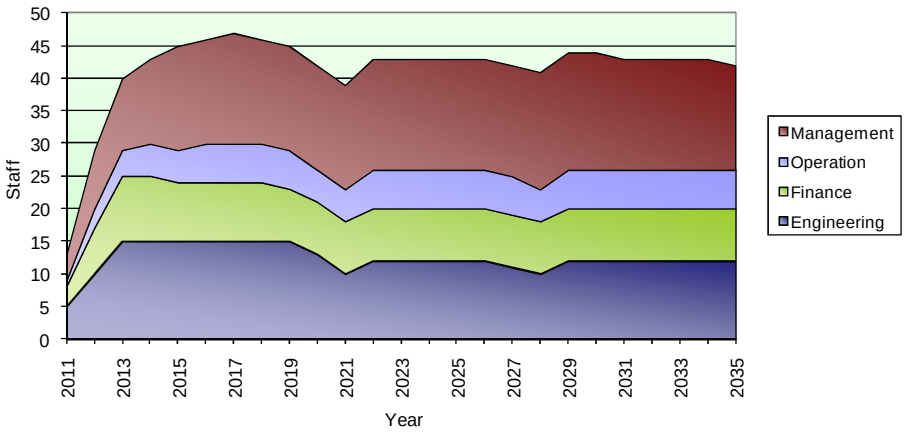
Management Structure

RetroSpace is a privately owned and managed company with a well balanced team of experienced and entrepreneurial space professionals. The company is structured into three primary business units:

- Operations
- Finance
- Engineering
- Management



According to the required corporate functions as described above, a detailed staffing plan for the company has been created. This profile is dominated in the early stages by the system design and development activities. After the system design phase, the employee composition is structured according to the needs of the service oriented focus with increased staff supporting management, administrative, procurement and operations tasks.



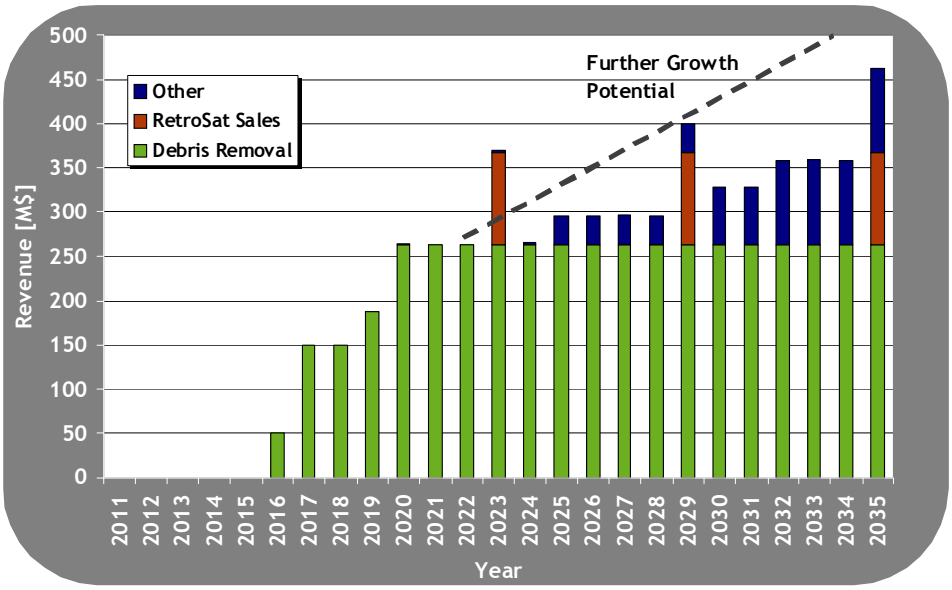
Financial Profile

Revenue Projections

The primary source of revenue for RetroSpace is from the Space Debris Removal Fund. Once RetroSat is flight demonstrated and successful, additional revenues will be generated from commercial applications of RetroSat's extensive capabilities.

Based on the planned launch of the first RetroSat, RetroSpace will begin creating revenues in 2016. After a successful debris removal demonstration, RetroSpace will begin to deploy additional satellites and grow the core business. The fleet will be completed at full complement of seven RetroSats once the final two satellites are launched in 2020. At this stage, revenues for the space debris removal service will reach approximately $250 million per year.

With the core business successfully established and RetroSpace turning a profit, the additional applications of RetroSat will be exploited in order to continue the growth of revenues. This extension of services is expected to yield an additional $200 million in year 2035.



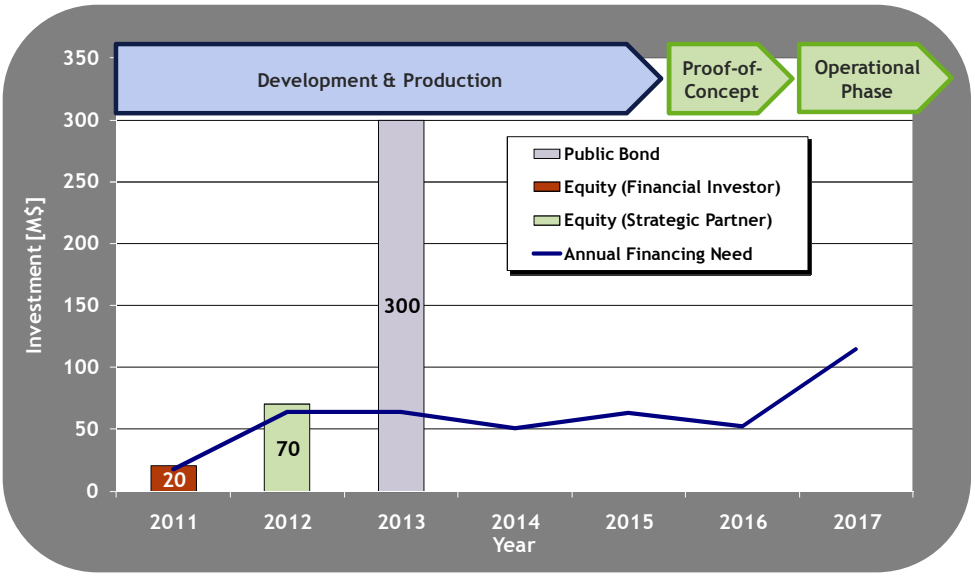
Financing

Until revenues start flowing, the financing need of the company is covered through equity investments of the company founders and venture capital (20 M$) in the first year and a strategic deal with a satellite manufacturer (70 M$) in the second year.

Complementing these investments, the majority of the required investment costs will be provided through the implementation of the government-backed "Clean Skies Bond" worth $300 million in 2013. Guaranteed by governments rather than using RetroSpace assets as collateral, this bond enables RetroSpace to enter into business with the following major financial benefits:

- No major grants required from the public sector
- No dilution of ownership or bank liability
- No risk to the issuing financial institution or its customers

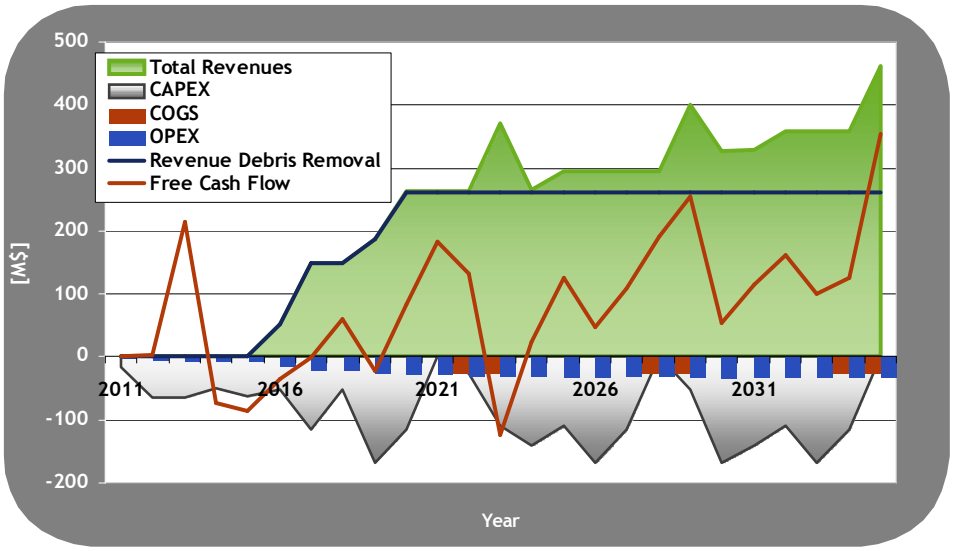
RetroSpace will be able to gain the required government backing of the “Clean Skies Bond” due to our extensive lobbying efforts, and the fact that we provide a necessary public benefit for the international community.



The motivation of the satellite manufacturer as strategic partner in the early phase of the project is given not only through expected revenues, but also by the guaranteed sales of its satellites to RetroSpace. Through the participation in the development phase not only as subcontractor, but also as investor in RetroSpace, it is considered the de-facto satellite manufacturer for the follow-on and replacement phases. The manufacturing partner can expect to more than make this investment back simply in satellite sales profits, before considering the additional return from the expected dividends of RetroSpace.

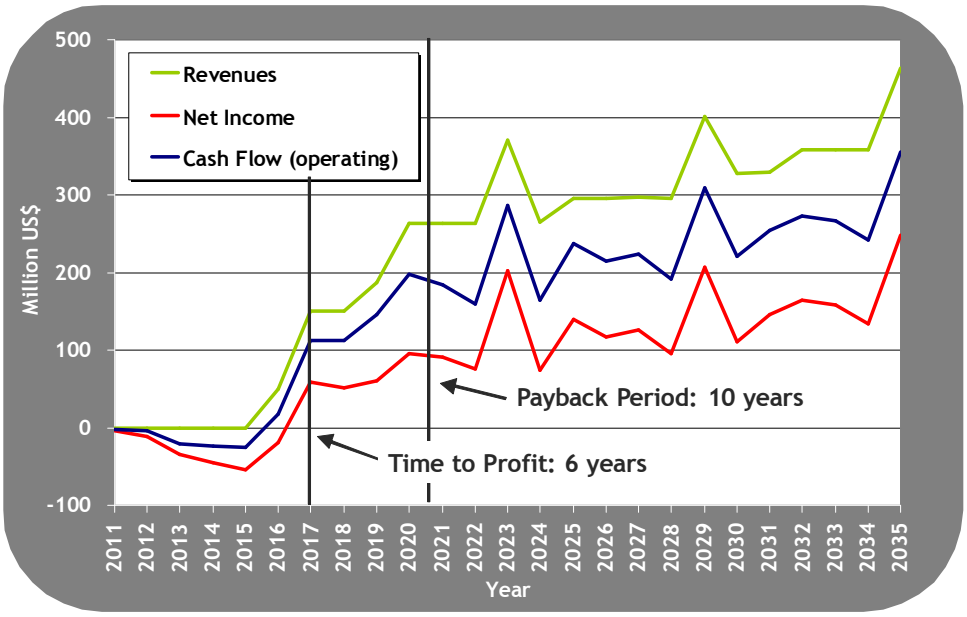
CAPEX / OPEX

The capital expenses and operating expenses are shown in the figure below. Operating expenses are dominated by staff salaries and ground station lease costs. Capital expenses are dominated by RetroSat manufacturing and launch costs.



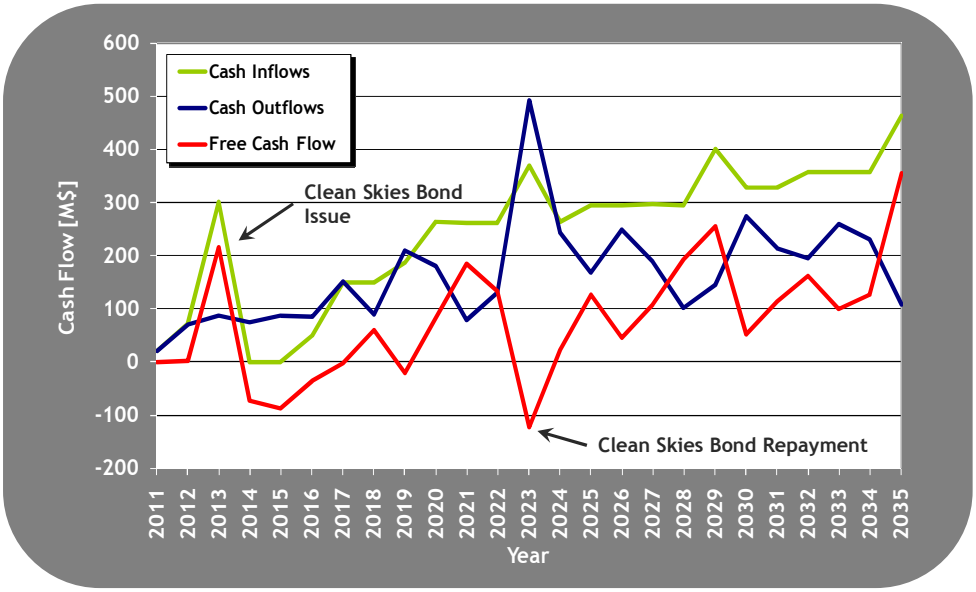
Profit and Loss

RetroSpace pro-forma financial results show it starts being profitable in years 2017, which makes a time to profit of seven years. The payback period is ten years (2020). From 2020 onwards, the performance of the business improves steadily, providing superior returns to its investors. The profit on revenues in 2035 is approximately 60%.



Cash Flow

The cash flow shows a steady increase, dominated by the contribution of the "Clean Skies Bond" in 2013, and its pay back in 2023.



Return on Investment

The RetroSpace solution provides value for all parties involved:

- The venture capitalist stake is acquired by the strategic manufacturing partner in 2017 for $100 million, representing a capital gain of $80 million and a multiple of five after six years (IRR of 31% p.a.).
- The satellite manufacturer has a phased, low risk approach towards a total investment of $170 million which secures revenues to his business of $1.3 billion over the planning period to 2035. At that point the manufacturer holds 95% of RetroSpace - a healthy and profitable business generating approximately $450 million in revenues p.a.
- In 2035 the original founders retain 5% of RetroSpace.
- Through the “Clean Skies” bond issue, the general public is offered a guaranteed annual interest income of 5% p.a. over 10 years.
- The government of RetroSpace headquarters will generate tax income of more than $600 million during the whole planning period.
- Business generated by RetroSpace for other space industries (such as insurance and launch service providers) totals over $750 million.

And through it all, over 300 of the most hazardous debris objects are removed from orbit, protecting the several $100 billion p.a. global space industry. This benefit is offered at a total cost to international agencies that represents less than 0.4% of their annual global public space budgets.

Conclusions

There is a clear need to solve the threat posed by orbital debris. RetroSpace has a well conceived plan to first create the market, and then serve this public need while simultaneously delivering value for all parties involved. RetroSpace is the only company to offer a comprehensive solution that is:

- Effective:
  - RetroSpace removes over 300 of the largest and most hazardous debris from the most congested regions in space.
- Responsive:
  - RetroSpace utilizes proven and existing technology to address the problem today, rather than wait for tomorrow. We have the technology!
- Global-minded:
  - RetroSpace recognizes the international context of the issue and provides an internationally acceptable solution.
- Flexible:
  - RetroSpace provides a technical platform that can be applied in any Earth orbit (not just LEO), and has the capability to perform useful services beyond the removal of debris.
- Affordable:
  - RetroSpace provides a beneficial service to both society and industry which requires minimal government funding. In fact, governments are not required to contribute any money in the first five years of operation.
- Sustainable:
  - RetroSpace establishes a framework to provide a public benefit with commercial efficiency on a long term basis.
- Profitable:
  - RetroSpace offers great financial returns for investors with minimal risks.

RetroSpace is the only company offering a comprehensive solution to reduce collision risk and secure access to space.

The RetroSpace Team

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