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ANALYSIS OF RECENT SATELLITE LAUNCH NUMBERS AND THEIR FUTURE MARKET EXTRAPOLATION

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In this paper we present an in-depth analysis of satellite launches in the mass range beyond 1000 kg from the year 2006 onwards based on several databanks and satellite lists, like the CEOS Earth Observation Handbook or the AGI Spacecraft Digest. We elaborate various evaluations regarding multiple satellite properties, such as mission purpose, orbit type, launch mass and satellite origin and describe developments and trends in these properties. By extrapolating from the collected data, we further discuss possible future scenarios of the market development and implications on future launcher requirements. The first scenario only recognizes current mission and satellite types to extrapolate possible launch numbers in the future. The second projection includes an increase in launch demands caused by the introduction of new technologies in addition to current spaceborne applications, like space debris removal, commercial human space flights and space tourism. We i.a. show that the importance of Earth observation satellites is increasing and that European satellites are about equally numbered as civilian US satellites. We further discuss launcher requirements and the need of sustaining launcher families because future satellite demands in the given mass range are too diverse to be efficiently covered by a single launcher. The analysis includes data about commercial and public satellites, manned spaceflight and its support missions but excludes military satellites, which are unlikely to be open for launches by a general market instead of strictly national launch programmes (e.g. those from the USA, Russia or China). Overall 321 vehicles are part of the analysis.

I. INTRODUCTION

In order to anticipate and evaluate a possible development of the space sector as a market demanding launch services for various mission purposes, we have accumulated the data of the satellites launches in the years 2006 to 2010 and on those already planned for the years 2011 and beyond.

Payload mass specific transportation costs are reduced by large launch numbers, therefore analysis of these provides a tool for cost estimation of launch vehicles. Launch costs for satellites in geostationary orbits (GEO) become less sensitive for launch numbers above 6 [1].

Due to their prominence we focused exclusively on launches serving Earth orbiting satellites, including manned spacecraft or support vehicles for human space flight, such as cargo carriers.

We restricted the evaluation on satellites in the mass range of 1000 kg and above for evaluation of large launcher programmes. At the same time we excluded military satellites of nations with own space programmes, i.e. the People's Republic of China, the Russian Federation and the United States of America, as such satellites will most likely be served exclusively by their respective nation's of origin own launchers.

The following analysis will present and evaluate trends in the current satellite market and we will subsequently discuss two possible future scenarios, one regarding a non-changing demand in launch numbers and another describing a growth in launcher demands by reckoning in satellites with up to now not used purposes, like space debris removal, on-orbit maintenance, etc. Both scenarios will consider the cyclicality of launch numbers during extrapolation, which is known to occur in the space sector [2].

The data used for this analysis was obtained from various, mostly online, sources [3 to 10].

It needs to be noted that due to the fluctuating nature of the space sector business, where it is not uncommon for satellite missions to be postponed by months and even years or become cancelled altogether, these lists cannot be comprehensive. They should nonetheless be able to provide an argumentative basis. In total 321 launched or to be launched vehicles have been considered in this analysis.

II. METHODOLOGY

To investigate the launch numbers of recent years we accumulated the launch data of all satellite launches from the year 2006 onwards, including launches planned for the future and sorted it into a database. The

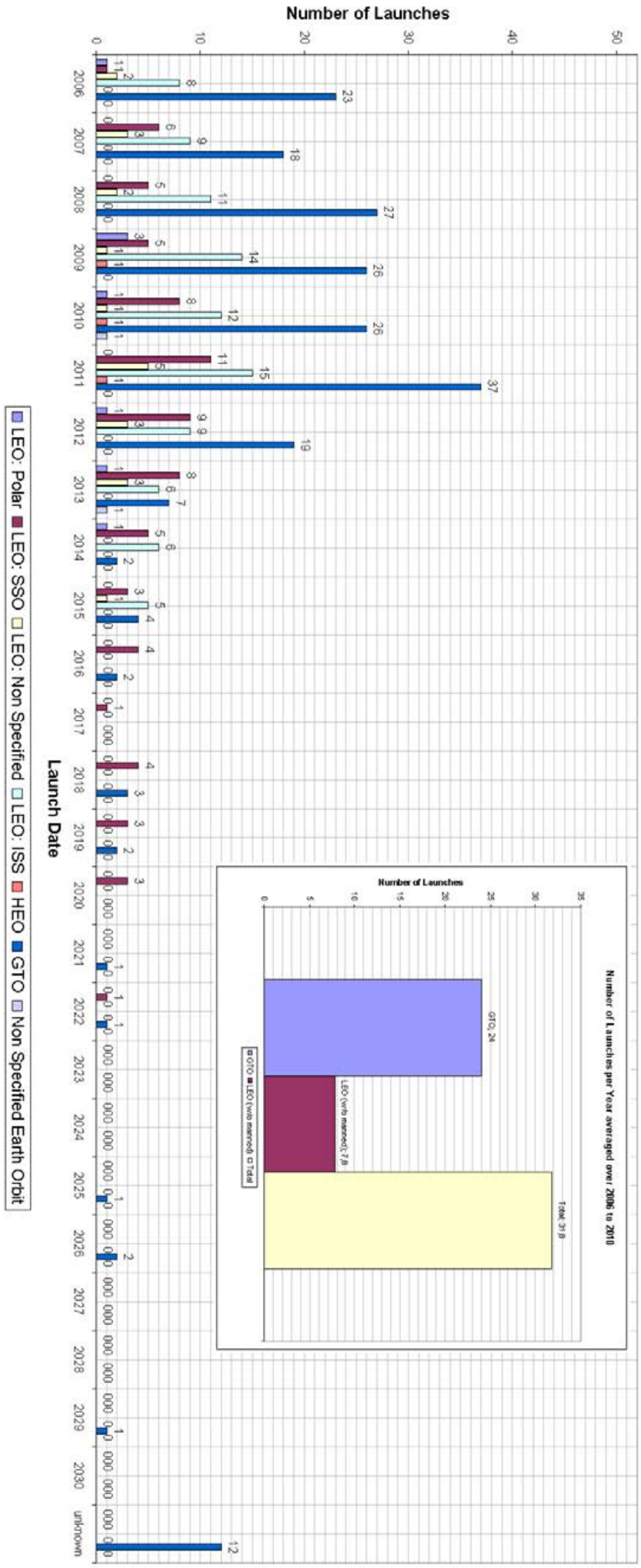

Fig. 1: Number of launches per orbit type over launch date as known in early 2011 along with average numbers evaluated for 2006 to 2010.

data of about 750 satellites was obtained from various sources [3 to 10], of which 321 were taken into further consideration due to the given mass range of minimum 1000 kg and by excluding those satellites that are unlikely to be launched by non-national launch programmes, i.e. military satellites of the USA, Russia and China.

For 62 of these 321 we estimated the launch mass, as it was unavailable at the time of the analysis. The estimation was based on data about the respective satellite bus, i.e. earlier satellites of the same type, and if available information about the planned launcher. In case the data was insufficient data even for an estimate, we did not include any mass in the data accumulation and the satellite was not considered in the subsequent analysis.

III. STATUS QUO OF SATELLITE LAUNCHES

III.I Launches per Orbittype

Figure 1 shows the launch numbers of all the satellites, which were part of the analysis, as known in early 2011, sorted by mission orbit type.

It can clearly be seen that the launch numbers are fluctuating significantly, e.g. GEO satellite launches vary between a minimum of 18 launches in 2007 and a maximum of 37 launches in 2011. However the latter can possibly be attributed to the fact that several satellites have been postponed from 2010 to 2011 and more will be postponed from 2011 to a later time during the course of the year as the number of possible total launches is restricted.

When considering the years from 2006 to 2011, it is obvious that the total launch numbers increase significantly. In 2006 a total of 35 satellites were launched, in 2007 it were 37, followed by 45, 49 and 50 in the next three years. For 2011 a number of 69 launches were planned at the time of the analysis, which is a larger increase within one year than that over the course of the previous 5 years. It is therefore probably still subject to change for the above mentioned reasons. In 2012 the launch number drops to 41 launches, more to the size of that of the years 2006 and 2007.

This drop in launch numbers for the post 2011 period is to be expected, because launch plans are not yet consolidated or published.

The increase of launch numbers is most prominent in the years 2008 to 2010, where the launches of GEO satellites were almost constant at about 26 launches. Increases can be observed in the low Earth orbit (LEO) launch numbers, namely for polar, sun-synchronous (SSO) and missions targeted at the International Space Station (ISS).

It can also be recognized in Figure 1 that flights to ISS are dominant in the LEO spectrum, varying between 8 and 15 launches per year until 2011. SSO missions are also very important and outrank all other LEO orbit types, with the exception of the year 2006, when non-specified LEOs had one launch more.

In the given mass range of minimum 1,000 kg there are no launches for medium Earth orbit (MEO) and only few High elliptical orbits (HEO) launches.

Adding everything together, it is clear that GEO satellites are dominant and will most likely contribute significantly to the future launch requirements as well, as a decrease in communication demand is not to be expected.

Averaging the numbers from 2006 and 2010, about 31.8 satellites were launched per year in the openly accessible launcher market. Of these a mean value of 24 satellites were headed for a GEO and 7.8 for a LEO, not regarding missions for human spaceflight.

III.II Launches per Mission Purpose

In Figure 2 the launch numbers are presented over mission purpose. Due to scarcity general science and technology development missions were put into one group – it is clearly visible that their contribution to launch numbers is small (between 1 and 2 launches a year), which is to be expected as especially technology demonstrator missions are usually executed with small and thus cheap satellites due to the involved risks. Therefore they are mostly outside the satellite category subject to our analysis.

Earth observation and reconnaissance satellites show the second largest share of missions in Figure 2 (between 2 and 20) and their numbers increase over the years, which we attribute to the fact that several nations begin using satellites for military or civil reconnaissance (e.g. Germany with the TerraSarX mission, launched in 2007 and TerraSarX 2 to be launched in 2013). The importance and interest in such remote sensing missions is also stressed by the fact that in the post 2011 period, there is a significant number of missions already known today with that mission purpose and all of the missions known in the period after 2015 are of that mission purpose, not counting in those satellites of which the launch dates are unknown.

Other mission purposes do not show such significant numbers for the coming years, including communication, even though the largest share of already flown missions lies in that field (between 18 and 34). This matches the numbers for GEO satellites in the previous paragraph as such satellites are mostly communication satellites.

While navigation was not ruled out as such during the analysis, the US Global Positioning System (GPS) and its counterparts in Russia and China are military programmes and are therefore outside the scope of this work. Europe's Galileo programme contains satellites,

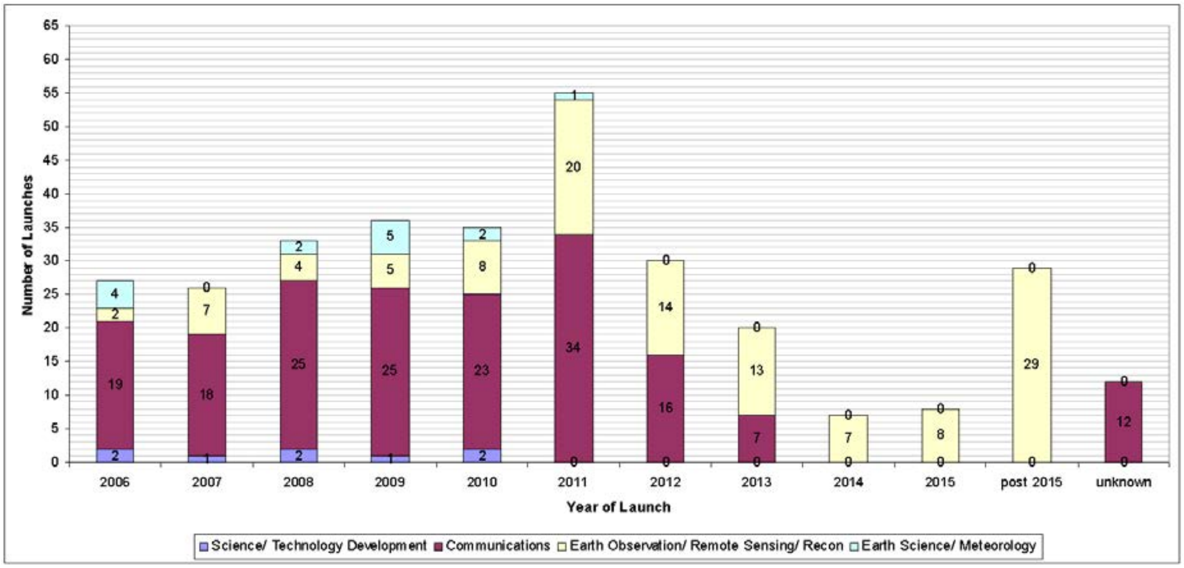

Fig. 2: Number of launches per mission purpose over launch date.

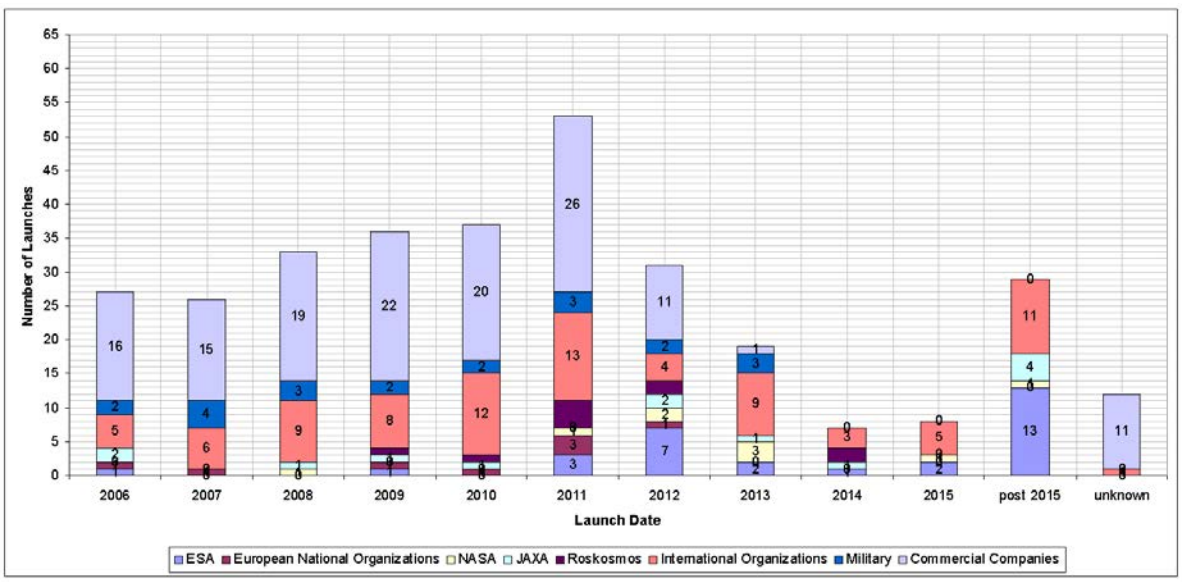

Fig. 3: Number of launches per operator over launch date.

which are below the mass limit of 1000 kg (namely 640 kg [3]) and thus are neither included in this analysis.

III.III Launches per Operator and Origin

Figure 3, Figure 4 and Figure 5 illustrate the variation in launch numbers with regard to the operator and origin of the respective satellite.

The first two figures clearly show that in the given range of satellites, commercial satellites have the largest share on the total launch numbers, namely 57.9% averaged over the years 2006 to 2010 (Fig. 4) resp. between 16 and 22 launches in the given timeframe (Fig. 3). Military satellites, even without the major contributions of the not counted in US, Russian or Chinese programmes, still have a significant share in the total numbers, i.e. 8.2%, the third largest one. Furthermore there is a rather stable number of about 2 military launches each year. The second largest share, 25.2%, is taken up by non-european national organizations, aside the individual ones presented in addition. European national programmes only have a small share, 1.3%, as many European missions in the given mass range are ESA missions.

It is notable that Roskosmos, ESA and NASA together have about the same number of Earth orbiting missions as JAXA alone, which underlines JAXA's intention to install a system for monitoring and evaluating the climate change and make forecasts with that regard [12].

Concerning the origins of the satellites, Figure 5 shows that civilian US satellites are about the same number as European satellites, both only varying slightly between 7 and 9 launches until the year 2010. However in the post 2015 time frame, Europe currently has the largest contribution, i.e. 13 launches.

China's launch numbers are varying more strongly, between 1 and 7 launches per year, but each year there is at least one launch from the People's Republic. The rest of Asia contributes several satellites, between 2 and 4 each year, with the exception of 2011 which has a significant increase to 11 launches. Examples of Asian missions include mostly communication satellites like LaoSat or Measat from Laos resp. Malaysia, which points out that even smaller countries are interested in space applications. Japan has also a continuous contribution, mostly on lower numbers, between 1 and 2 launches per year.

Africa, Australia and South America only have small and irregular shares in the total launch numbers each year. It remains to be seen if these nations follow the lead of the before mentioned Asian nations and increase their demand in satellite launches.

III.IV Average Masses over Orbit Type

Figure 6 provides an overview over the mass range of the satellite launches in the years 2006 to 2010.

It can be seen that the share of HEO satellites is insignificant and too small to make an endurable statement.

Furthermore the masses for LEO satellites are clearly concentrated on the lower end of the analysed mass range, i.e. between 1,000 and 1,999 kg, falling off to the larger mass range significantly. Considering that they do not need apogee motors, etc. this is to be expected.

The mass distribution for GEO satellites is less strict and is thinning out at the edges, i.e. in the mass intervals below 2,000 kg and above 6,000 kg. The largest spike in numbers is for masses between 4,000 kg and 4,999 kg. Current programs for small GEO satellites, like Small GEO by OHB-System [13] might shift this distribution in the future, if successful.

III.V Status of Human Spaceflight

In Figure 7 the launches with regard to ISS operation are listed, i.e. missions with cargo flights to ISS and those with crew flights.

There is an increase to 4 crew launches per year on 2009 due to the increase of the permanent ISS crew size to 6. The drop-off in launch numbers after 2012 is due to not yet finished launch plans and today it can be assumed that the 4 manned launches will continue until the planned operation end of ISS at the earliest in 2020.

In average about 4,500 to 6,000 kg of cargo payload are needed per cargo flight to ISS to support the operation with 4 crew flights, as can be seen at the bottom of Figure 7.

The number of cargo flights is about 6 to 8, which includes the Automated Transfer Vehicle (ATV), H-2 Transfer Vehicle (HTV), Dragon and Cygnus launches.

The increase of the total cargo has a peak in 2011, which is due to the delay in the shuttle launches and the launch of ATV 2 and HTV 2. Not considering peaks, a total of about 10 launches are needed to operate ISS with the current spacecraft for crew and cargo transport.

Figure 8 illustrates the total launch mass of current and planned support craft for ISS (with the exception of Dragon, where a total mass was unavailable at the time of the analysis) and their payload masses. It can be seen that the newer support craft like ATV and HTV have larger launch masses than the older Progress cargo craft. This points out the necessity of keeping up the ability to launch such large masses if those new developments should not be discarded after few uses. Cygnus is an exception to the mass increase of support craft, which is possibly attributed to the fact that it is based on the Multi-Purpose Logistics Module and not a totally new development.

IV. FUTURE ESTIMATIONS

Based on the data elaborated above we extrapolated two scenarios, one considering only the current mission types, i.e. a continuation of the status quo. The second portraits an increase in satellite launches due to new applications, e.g. space tourism or debris removal.

A further basis for the extrapolations are the satellite lifetimes of 5 to 7 years for LEO missions and 12 to 15 years for GEO.

IV.I Scenario 1: Continuation of Status Quo

Given the satellite lifetimes it becomes clear that the GEO satellite part of this analysis, will require re-launches to keep up the current needs in communication and other payloads in the early to mid 2020s.

LEO satellites will have to be replaced earlier according to their respective launch dates and lifetimes.

To extrapolate on a possible pattern of the future requirements, we repeat the pattern of launches as given in the time range of 2006 and 2010 with random noise but resulting in the same average numbers of launches.

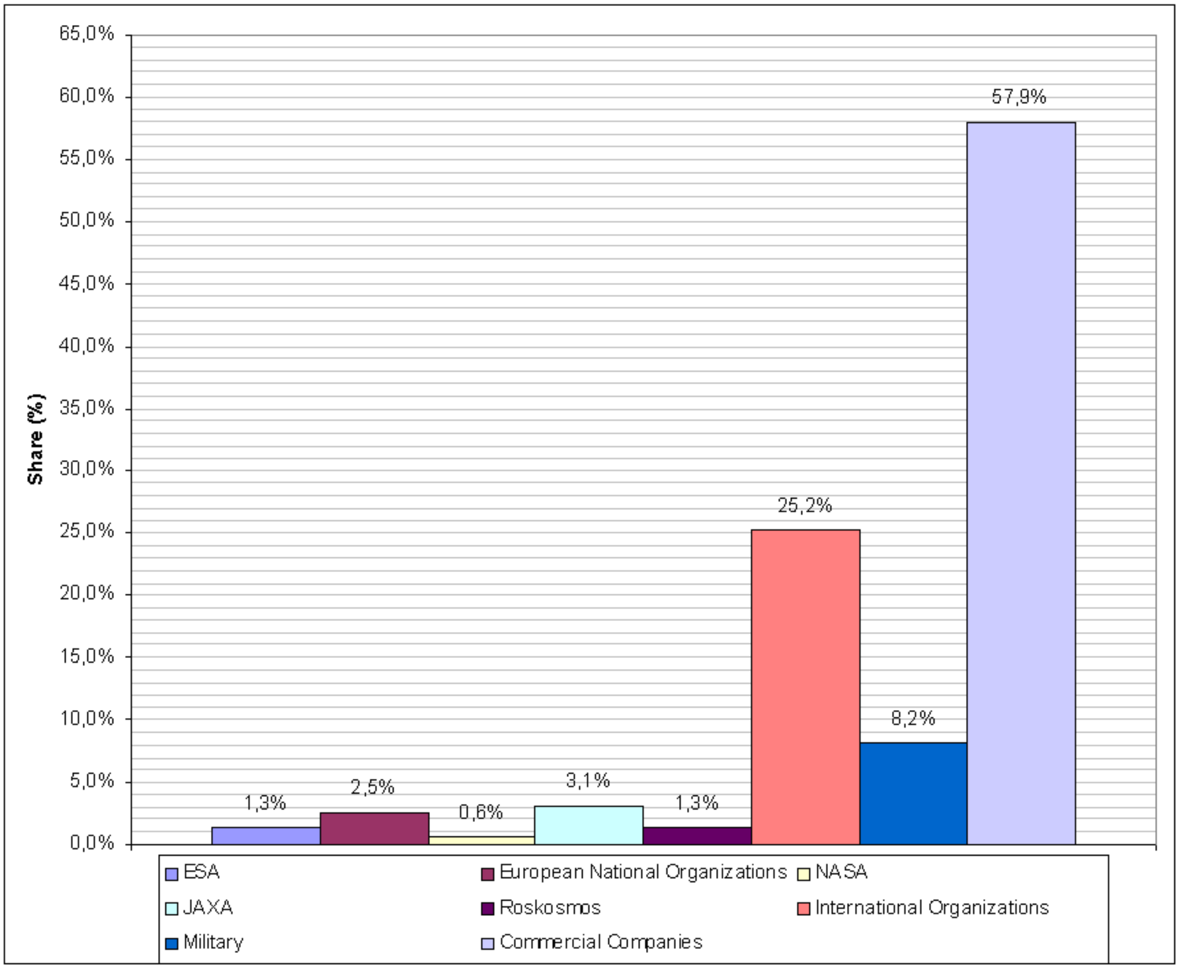

Fig. 4: Number of launches per operator, averaged over the years 2006 to 2010.

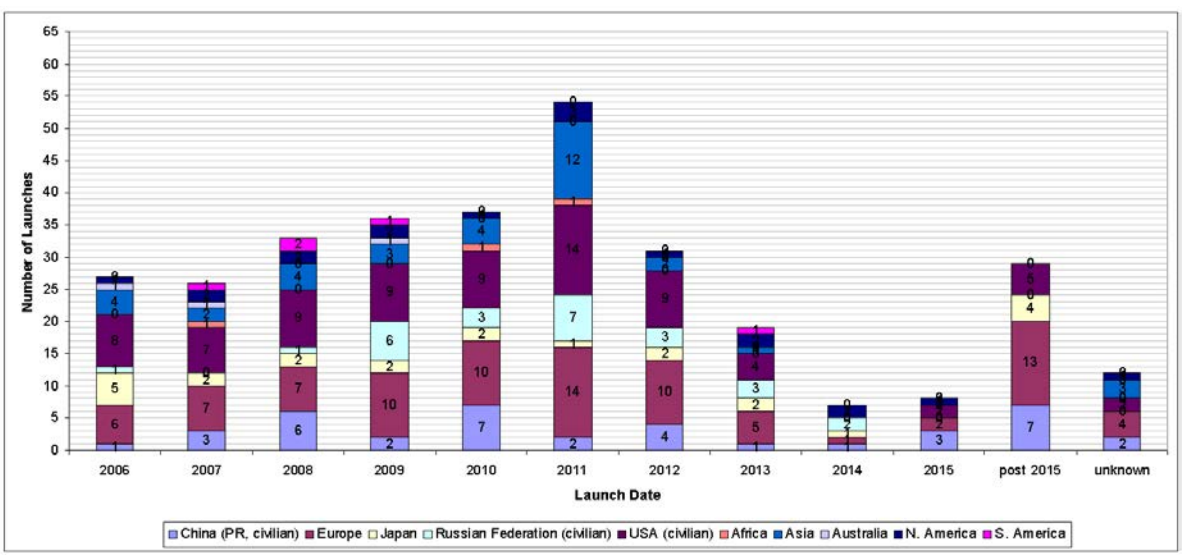

Fig. 5: Number of launches per origin over launch date.

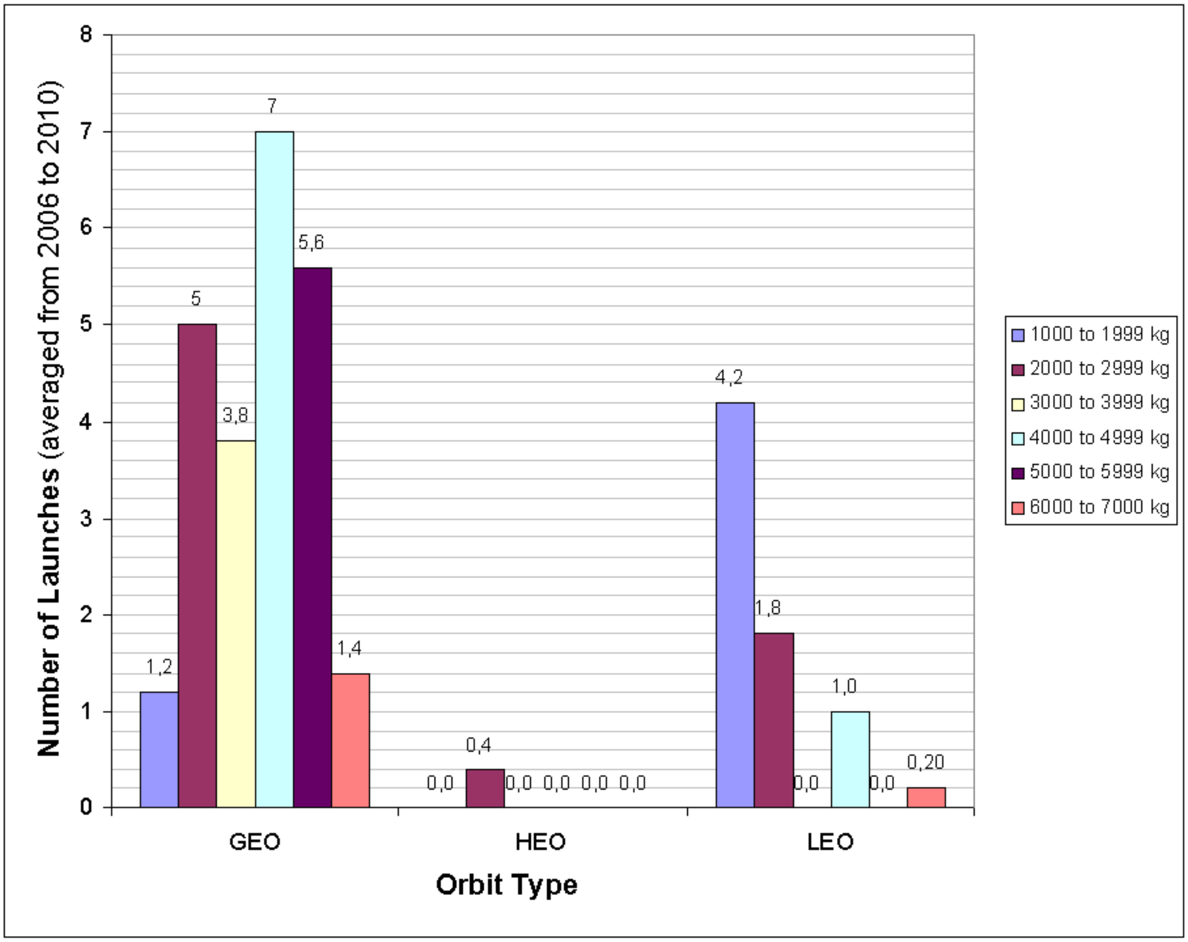

Fig. 6: Number of launches per mass interval averaged over the years 2006 to 2010.

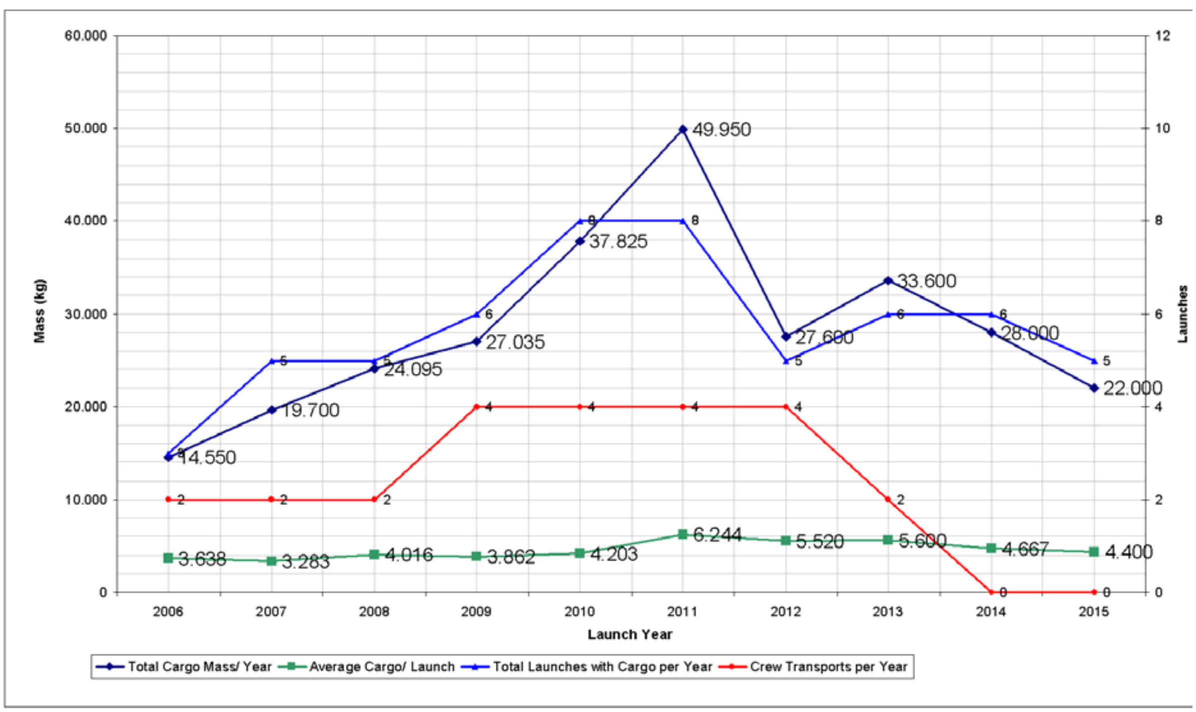

Fig. 7: Number of launches and masses for human spaceflight.

A possible outcome of such a scenario can be seen in Figure 9, for a timeframe of 15 years, starting with 2020. Due to the long lifetimes, the frequency of repetition is smaller for GEO satellites than for LEO ones. The LEO patterns are less distinct due to the added noise to account for non-precise patterns.

This continuation of the status quo is also used in the more elaborated future scenario as we assume that the status quo is the minimum launch number requirement.

1. From 2022 onwards: Technology demonstration or testing for manned spaceflight, usage of commercial infrastructure => increases in launches per year: 2 support flights for ISS (not necessarily targeted at ISS but of comparable launch effort)

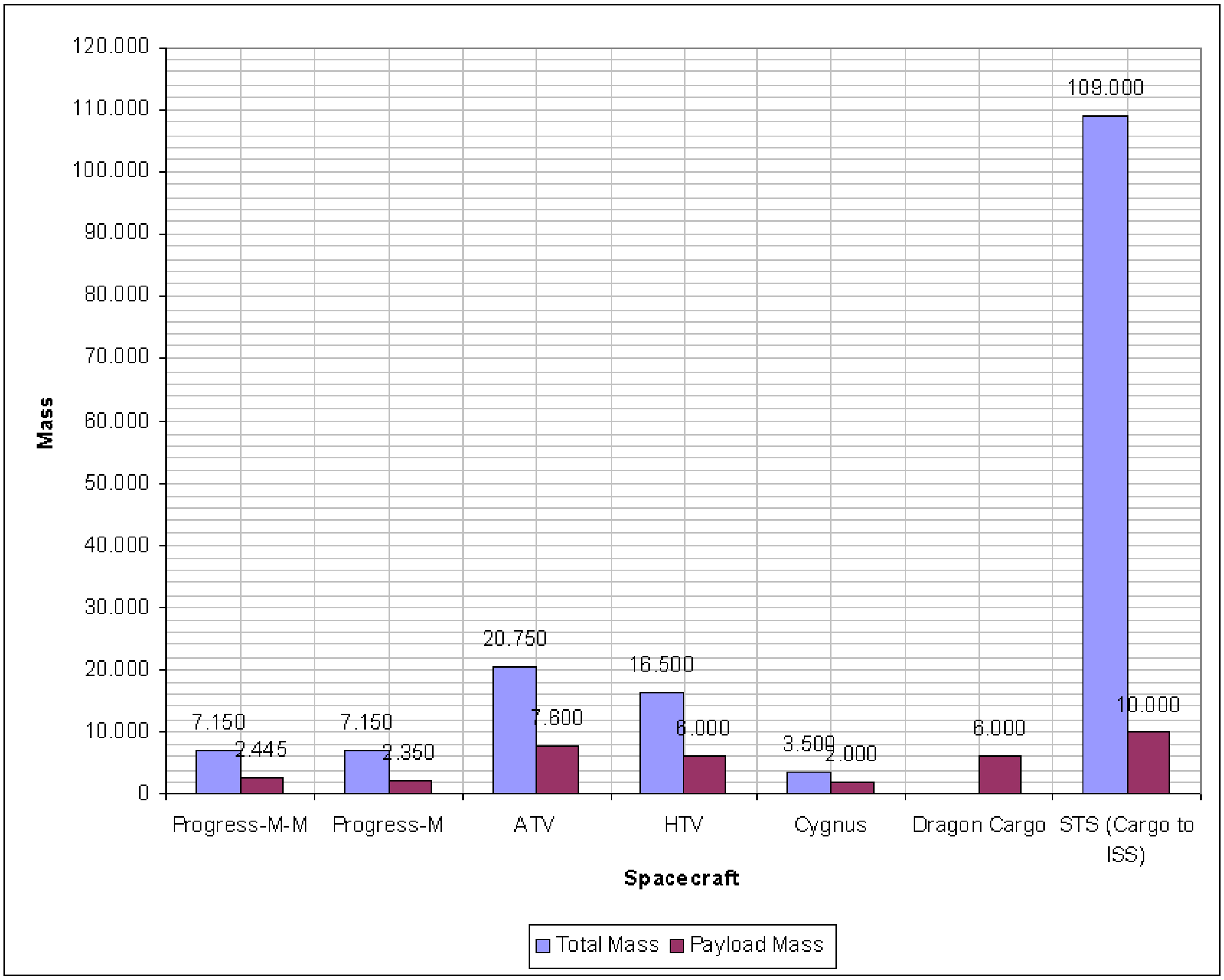

Fig. 8: Number of launches per origin over launch date.

IV.II Scenario 2: Growth in Launcher Demands

The continuation of the status quo is also used in the extended future scenario as we assume that the status quo represents the minimum launch number requirement.

In this scenario we also consider increases due to new mission types and e.g. commercial endeavours, also including manned space flight (e.g. Bigelow Space Hotel, ATV Evolution, etc.). Conservatively we assume the continuation of the status quo until the early 2020s. Afterwards we assume the following developments:

2. From 2026 to mid 2030s: Ten years after the original end of mission date, ISS is either overhauled or a new LEO infrastructure is built, possibly with commercial or Chinese collaboration => increases in launches per year: 1 cargo launch with a station module, 2 cargo launches with equipment (batteries, cables, tanks, etc.) and tools, 2 manned launches for construction work; decreases in launches per year: to regard reductions in operation room and time of ISS/ its successor, only 2 crew launches and 3 cargo

launches are included in the calculation for the time of the construction work

3. From 2030 onwards: Occurrence of new missions like on-orbit servicing, debris removal, on-orbit manufacturing and energy harvesting (for technology tests and later application) => increases in launches per year: 2 LEO and 2 GEO launches

These developments are depicted in Figure 10. It can be seen that the average LEO launches have increased by 2.5 launches a year, whereas the GEO numbers have only increased by 0.75 launches a year in average, representing the fact that most innovations regarding astronautics are currently focused on LEO missions (notwithstanding manned exploration of more distant targets, which have not been part of this analysis). Overall current plans and developments are focused on LEO applications, which is also one reason why their increase outweighs that of GEO satellites in this projection.

IV.III Influence on Launcher Requirements

Regardless of the actual progress of launch numbers, one requirement on future launchers is the sufficient launch capability to lift the necessary number of payloads into orbit.

When only regarding the current status quo, besides the launch numbers, it is necessary to have launchers with GEO payload mass of up to 7,000 kg and LEO of up to 20,000 kg for payloads such as ATV, etc. Even though the continued operation of ISS has not yet been decided beyond 2020, it is probable that manned spaceflight will go on even after 2020 [11] and therefore comparable payloads possibly need to be launched even after the current ISS end of life. This is supported by the fact that Russia declared prolonged operation of its station modules [14] and the planned creation of an own space station by China [15].

Therefore the current launchers will be required for future missions as well. A reduction in launcher capabilities is not possible, if the current plans are to be kept up and additionally such a reduction below the current status quo would also risk loss of know-how and mastery of high technology.

The broad ranges of masses, i.e. low masses for LEO satellites (mostly below 2,000 kg), large masses for LEO human spaceflight (up to ca. 20,000 kg) and large masses for GEO (up to 7,000 kg) make it difficult to encounter these demands with a single launcher – whole launcher families will also be required in the future. As stated before, however sharing the launch numbers with several launchers will increase the payload specific costs. An alternative would be usage of multi-launch systems, which decreases the flexibility and increases the risk of delaying several satellite missions if one satellite is behind schedule.

When regarding a growth in launch numbers, we assume this future projection as conservative regarding launch numbers and launch dates, especially regarding manned spaceflight, where commercial interest is increasing [16, 17].

In addition to the rising launch numbers, the demands for manned space flight create more challenging requirements for reliability and launchable payload mass. Whereas ISS was constructed using Proton and the Space Shuttle as heavy lifter, future stations cannot rely on the latter for construction. Considering that there is an increased demand in numbers (due to national and commercial endeavours in manned spaceflight), a lack of supply in launch services could result in larger costs for each individual station and therefore risk cancellation or delay of such projects, if no sufficiently reliable or numerous launcher exists.

Due to the increased complexity of manned spaceflight delays due to development problems are also to be expected.

Summarizing at least two different launcher categories will be required also in the future.

One launcher that is capable to handle smaller, less numerous launches into LEO, of masses typically not exceeding 2000 kg (cf. Figure 6), mostly into a sun-sychronous orbit.

Another launcher would be required to cover more numerous (and broadly ranged in the mass spectrum) GEO launches of a payload mass of up to about 6000 kg.

Depending on the future developments regarding human spaceflight it can be assumed that such a medium GEO launcher could also carry heavy LEO payload into orbit.

If it should prove successful, a launcher capable to efficiently support small GEO missions would also be needed. This could possibly be combined with the medium launcher for ordinary GEO missions, if several small GEO satellites are launched together.

V. CONCLUSION

Based on an analysis of recent satellite launch numbers, we presented possible future developments in the launcher market for satellites of masses from 1,000 kg upwards and which are not restricted to national space programmes (such as US military satellites).

We have shown that GEO satellites have demands in launch numbers which are about three times as high as those of LEO satellites and that communication satellites dominate with regard to mission purpose, although the number of Earth observation satellites currently increases as do the launch numbers for polar and sun-synchronous orbits.

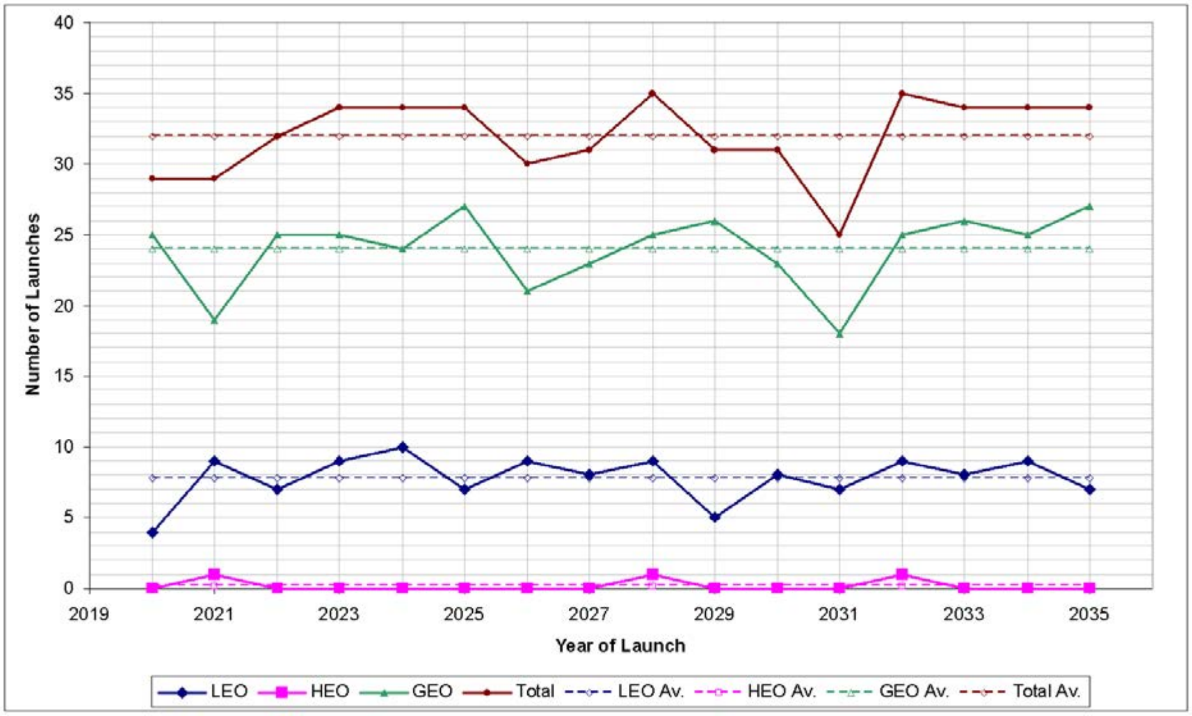

Fig. 9: Possible launch numbers for a stagnating future scenario

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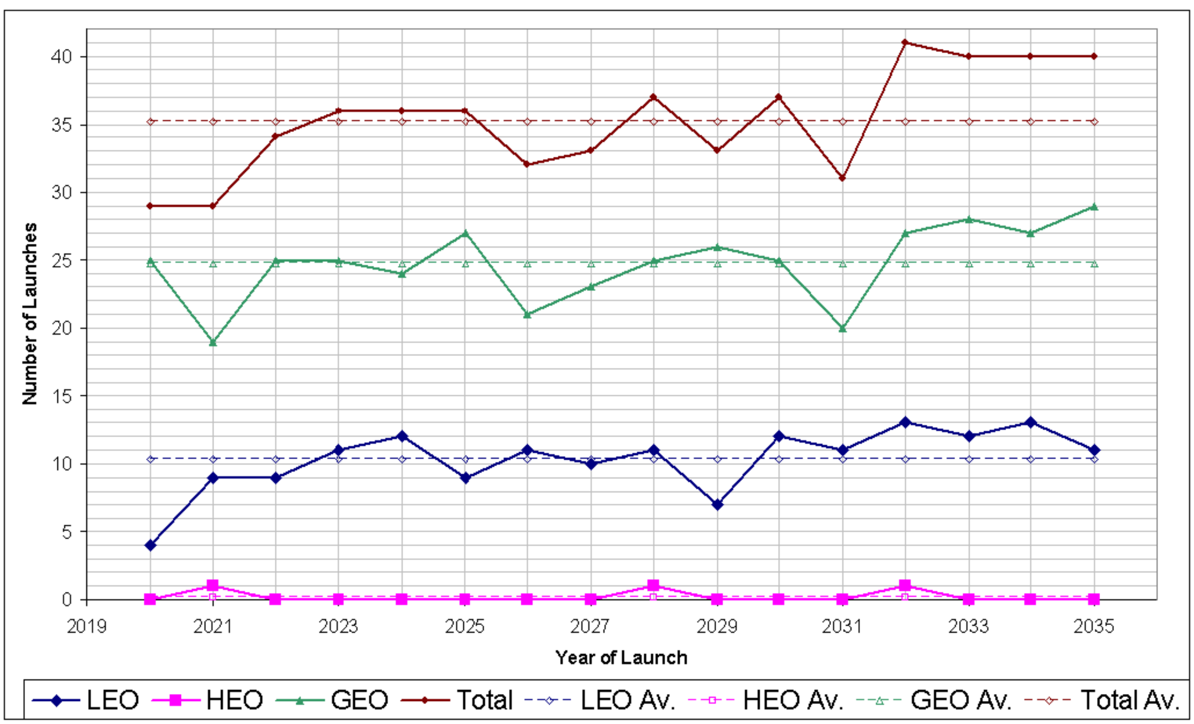

Fig. 10: Possible launch numbers for a future scenario with increasing demands.

Furthermore disregarding military satellites, it was pointed out that Europe and the US launch about the same number of satellites in the given mass range.

We elaborated the variance in launch masses and it was shown that LEO satellites have significantly lower masses than those targeted for GEO, which have a broader range of masses (typically between 2,000 kg and 6,000 kg).

We also described the current situation considering human space flight.

Regarding future development we presented a projection of the status quo and a conservatively growing scenario, which is significantly influenced by manned spaceflight, including commercial endeavours.

In addition we pointed out the challenges in meeting the requirements of such future scenarios with future launchers, stressing the need to maintain launcher families.

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