Risks and vulnerabilities of future satellite-based tracking systems

Miikka Ohisalo, Otto Tiuri, Tatu Urpila, Pasi Kämppi and Jyri Rajamäki

***Abstract*—** This study finds out if in the future, some special risks and vulnerabilities concerning satellite-based tracking and navigation occur. The concept of risks plays an important role in future studies and in all future thinking. To find out possible future risks, future research methods such as scenarios and weak signal identifications were being used. Forecasting the future is impossible, but the risks found are based on events that have already occurred or scientifically research of interesting phenomena. The risks found concern nature disasters, technical errors and political and economical situation worldwide. The future will most likely bring multiple new risks to the field of satellite-based tracking. Because of these risks, all the different end-users of satellite-based tracking need to be updated, both technically and mentally. The availability of different services will most likely increase as new service providers come to the expanding market in the future. Variety of the services is growing and the customer has to use more time and effort to find the best and most reliable alternatives.

***Keywords*—** Future research, Galileo, GLONASS, GNSS, GPS, Risk management, Satellite-base tracking, Satellite-based navigation, Tracking

I. Introduction

SATELLITE based tracking and navigation has gained broad popularity during past years. For several years the Global Positioning System (GPS), developed and administrated by the United States Air Force, has been available for everyone to be used [1]. GPS-navigator used to be a luxury item which could be found in just a few vehicles. Today anyone can get their own navigation devices with a small price. The GPS-system was the first satellite-based tracking system available in markets and therefore its name "GPS" is being used to describe all satellite-based tracking and navigation in everyday language.

A modern satellite-based tracking system combines the navigation and telecommunications technologies. The system is complicated and it consists of many technical segments, including the control segment, space segment, tracking segment, communication segment, data processing segment, application interface for external applications and end-user segment. The basic principle is that a tracked device is positioned by Global Navigation Satellite Systems (GNSS), and positioning data is delivered for post-processing via mobile networks, the internet or a secure network. The principle is portrayed in Fig. 1. [2]

The accuracy of tracking and navigation has been increased since the services became available. Many companies have also invested in satellite-based tracking systems and use them to track their everyday deliveries and transportation in order to be more efficient and secure. Earlier there has been only one satellite system available; the GPS developed by the U.S Government. Now Russia (GLONASS), China (Compass/Beidou) and the Europeans (Galileo) are aiming to the same markets with their own systems. The field of satellite-based tracking is becoming more diverse and these services are going to be used even more broadly by different organizations and private persons. This might mean also new risks [3]. This study focuses on possible future risks of satellite-based tracking.

This study, belonging to SATERISK project [4], [5] introduces possible risks of satellite-based tracking and navigation generally and from and logistics point of view. This paper presents multiple diverse risks some of which might sound even unreal or unlikely to occur.

II. Problem Formulation

The concept of risks plays an important role in future studies; risks are linked with the notion of uncertainty – an inherent quality of the future. With systematic using of futures research methodologies, alleviating uncertainties about the future is possible. When developing ways of anticipating the future—whether through scenarios, Delphi, mega-trend analysis, weak signal identification, futures wheel, etc.—the resulting foresight intelligence helps to reveal various alternative futures. The second layer of analysis consists of efforts to distinguish major risks. After a specifically orientated process of risk horizon scanning, the next steps are identifying relevant risks, assessing, interpreting, understanding, managing and governing them. [6]

In this paper, analysis of potential problems and brainstorming were used broadly as methods in investigation of risks. Because it is impossible to forecast or reliably

Manuscript received April 24, 2011. : This work was supported in part by Tekes – the Finnish Funding Agency for Technology and Innovation – as a part of the research project 940/08 SATERISK.

M. Ohisalo, O. Tiuri, T. Urpila and P. Kämppi are with Laurea University of Applied Sciences, Vanha Maantie 9, FI-02650 Espoo, Finland (phone: +358-9-8868 7400; e-mail: miikka.ohisalo@laurea.fi; otto.tiuri@laurea.fi; tatu.urpila@laurea.fi; pasi.kamppi@laurea.fi).

J. Rajamäki is Principal Lecturer and Scientific Supervisor of research projects at SIDlab Networks, Laurea University of Applied Sciences, Vanha Maantie 9, FI-02650 Espoo, Finland (phone: +358-9-8868 7400; e-mail: jyri.rajamaki@laurea.fi).

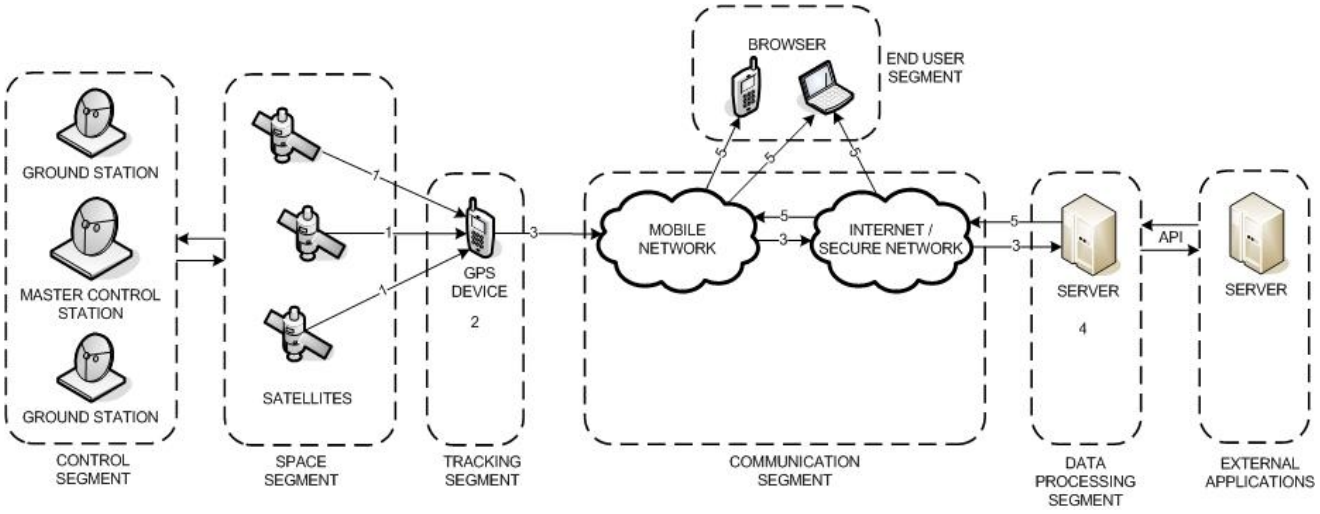

Fig. 1 Principle of satellite based tracking system [2]

research the future, imagination was needed and it was used among other methods of future research by making scenarios of the potential future risks. When examining possible risks of future, this study relies on some phenomena that already have taken place in past and might cause problems also in the future.

The Internet has been used widely to find references, because it is full of news and variable articles to support this paper. It was easier to find updated information of this subject from Internet than from traditional literature. Some references may not fulfill the scientific standards of good reference, but these kinds of references have been used to gain new thoughts and fresh ideas. Also it was made clear in the assignment of this study that these kinds of references can and should be used in this study as long as they are also openly compromised when needed. Not only these "unreliable" references were used, but also very reliable sources as well as interviews of professionals.

III. Problem Solution

A. Natural disasters

Latest natural disasters on earth have had significant and surprising affects on a global scale. A good example of this is the volcanic eruption in Iceland, which stopped the whole European air traffic for few days. Another example is Japan's earthquake and massive tsunami, which incurred such monstrous damage that most likely the current Japanese Quasi Zenith Satellite System (QZSS) program with three GPS-supplementary satellites [7] will be delayed.

These are the reasons why the possible effects of a natural disaster must be taken seriously while thinking the possible outcomes of the risks which could affect e.g. to fleet control or security systems.

B. Solar storms

The word solar storm means radical change in Space "weather" condition, in which the sun generates an enormous eruption of heat energy and electromagnetic radiation. When this type of storm reaches the magnetic fields of the earth, it generates electrical spikes in the electric distribution networks; it could also mean the breaking and malfunction in many electrical devices, such as communication and navigation devices. The worst-case scenario is that a solar storm could possible lead to global destruction of the electric distribution networks and brings down satellites of all types.

The devastating effects of a solar storm are the result of magnetic fields and radiation, which the storm pulls with it. Powerful electromagnetic radiation destroys the fine electronics of the satellites and that way makes them out of order. When the storm hits the earth's magnetic fields it causes huge electric spikes in high voltage power lines. The malfunctioning of the electric distribution network severely affects the controlling and using devices which are for example a part of a fleet control system. [8]

According to the U.S. space administration NASA, a large solar storm could cause devastating effects on a global scale; NASA has stated that it could bring twice as much destruction as the Hurricane Katrina did in New Orleans, except the devastation would be in global scale. [9]

The biggest solar storm measured in known history happened in 1859. If this scale storm should occur today it would paralyze the data traffic such as phone calls and messages, internet and television broadcasts. NASA has forecasted that a solar storm of that scale could happen in 2012-2013, because the activity of the sun is biggest at that time. According to NASA studies, a solar storm is most likely to happen, when the amount of sunspots is at its peak. Measurements have proven that this type of season occur in every eleventh year. [10] A small solar storm-like phenomenon is suspected to be the reason of a satellite

stopped reacting to the commands from earth in April 2010 [11].

If Solar storm should happen it would mean that the navigation with GPS and other satellite based fleet tracking and navigation systems would be out of order, it could significantly complicate the logistical processes. Also the distribution of gasoline to the fleet would be compromised, since most of the gasoline pumps work with electricity. The impacts of a solar storm would extend to all electronic devices, also to the controlling devices of fleet management operating systems. And not only to the navigating devices of companies and civil persons alike, but also to the satellites, which are the basis of those systems. This type of situation would likely be catastrophic to continuity of production and would at least cause major security risks to the organizations that depend on satellite tracking systems. [9]

1) Ash cloud from volcano eruption

In 2010 a massive eruption of a volcano in Iceland caused severe problems for air traffic in Europe. Almost all the flights were cancelled due to ash clouds that could have been able to cause damage to airplanes.

In this study, as a part of natural disasters, ash clouds from volcano eruptions were investigated as a possible risk for satellite-based tracking in the future. The idea was based on a supposition, that a massive ash cloud would be so thick that signals between the Earth and satellites could be blocked at least partially.

However, there seems to be no previous research on this subject, because the phenomenon is not very common. Only some slightly unreliable sources for information were found, claiming both that the ash cloud has and has not effect on satellite signals. These results were based on observations of individual people.

Anyhow, it is possible that an ash cloud could affect signal strength and cause loss of accuracy. But this would be quite unlikely to happen and it would affect only random users, not all. The volcano eruption should possibly be so big to affect the satellite-based tracking, that the loss of tracking would be a minor problem in comparison with the damage to whole human society. So far, as there are no results from scientific research on this matter, this phenomenon cannot be held as a severe risk for satellite-based tracking.

C. International crisis and conflicts

On a potential crisis situation, where satellite based tracking and navigating systems are used by both parties of the conflict, it is possible that the party that manages the operating systems of the navigation and tracking close the system from outsiders, so that only one that can use them are their own organizations, military and its allies. Also the possible global economical crisis could cause a situation where satellite based services are restricted due the problems of financing them.

1) Conflicts

In the near future there will be more satellite based navigating and tracking systems available to use, for example the Russian GLONASS and EU's Galileo systems. Also China is in a process of developing its own global satellite navigating and tracking system, which is named the Compass. In the future equipment are likely to support other systems besides GPS or multiple systems at the same time. Although one must remember that considerable risk is a situation where some parties want to exclude others from receiving their satellite signals. This type of situation could complicate the life of individuals and companies alike. [12] An international military conflict or uncertain economic stability could lead to these kinds of circumstances.

2) Economical crisis

A big economical crisis could affect strongly to the financing of satellite programs in the future. The most recent economic crisis led to cuts in the world largest space program in USA. Shuttle flights were canceled entirely, and huge budget cuts where implied to the program. [13] The budget cuts were also implied to the GPS system itself. Needles to say that this will cause problems by time, when the system gets older and new satellites are not launched to the orbit; the old satellites in the system will decay. The conclusion is that Problems with funding will increase the risk of satellites to malfunction, problems to keep up with continuity plan and finally to increasing disturbances and weakening of the signal in the user level.

3) Destroying satellites intentionally

The original GPS-system was developed to the use of US Military and it is still managed by U.S. Air force [14]. The GPS system was the first satellite based navigation system in the world and it was born to match the needs of military positioning and navigating [15]. Later on people saw the business potential in the system, and many years after the original launch it was approved for the use of civilians. The main users of GPS and other satellite positioning system around world are mainly the military organizations of different countries around the globe. In the possible conflict situations in future it is very likely that the fighting parties will try to cripple the satellite system of the enemy so that they can't use their satellite based weaponry or Intel systems. In a global scale this kind of situation would affect to other instances as well, or at least to those which are using satellite based protocols in their businesses. The increasing of well working satellite based navigation systems within big countries (USA, China, Russia, and India etc.) will increase the risk of conflict that will take place in the orbit. This kind of space conflict would only happen if the political situation would be unstable in the world, so it is very unlikely to happen at this time. A strategic and direct strike against the enemies' satellite system could be considered possible in a conflict situation because of two different reasons. The strike would not be judged so harshly on a global scale because there would not be any casualties, and secondly the benefits derived from the strike to the military would be huge.

As mentioned earlier many military systems of US and

other countries rely heavily to satellite positioning. China and USA have already had experimental missile strikes from ground to orbit based missiles, which are capable of destroying satellites. [16], [17] Destroying the satellites this way will also increase the risk of collision with space debris in the orbit.

D. Technical risks

The most potential risk in the near future when considering the satellite navigation would probably be the satellite system itself. The technology is getting older if not updated on a regular basis also other things like space debris hitting the satellites damaging or destroying them completely, and certain uncertainties in some situations. The satellite navigation is based on a network of satellites circling the orbit. The amount of satellites needed to power the network depends on the system, but in all the common systems such as GPS, GLONASS and COMPAS the amount is somewhere between 21 and 35 satellites total. If for some reason satellites are missing from the network, the overall quality and accuracy of the system is greatly reduced.

1) Problems with satellite technology

The most commonly used satellite based navigation system is the Global Positioning System (GPS). The GPS is managed by the U.S. Air force. To be operational and have the accuracy needed the GPS needs at least 24 working satellites in the orbit [15]. Today, the system had 31 operational satellites [18]. The system was originally developed to the use of U.S. military. These days the GPS is available for everybody who has the hardware needed to make use of it. The system is still being managed by the U.S. Air force though, which causes it to be unreliable in the event that some party not favored by USA wants to use it to gain its own benefits. It is commonly known that USA can affect to the accuracy of GPS system and if needed even jam the signal from others. In an international crisis situation, where the benefits of the USA are threatened, the GPS is not the most reliable system.

Before there has only been hardware available at the market that supports the GPS standard, but in the future the consumer can choose from a large variety of options. Some of the satellite based navigation systems are built to support each others. So in the future it is possible to use many systems at the same time with same hardware, e.g. GPS and Galileo. In any case the problems pictured earlier on the paper could be relevant with other systems as well. The competition between the standards could cause problems as well. The increasing amount of hardware and systems brings also a large variety of new protective measures and protective standards to the navigation field. New systems may vary between each other and may bring issues and problems with it. Also the reliability of the systems may vary. That could be a problem when a system has to be chosen to match the needs of a logistical or any company that uses satellite based navigation to operate its businesses.

2) Aging of satellite technology

One of the risks threatening the satellite-based tracking is insufficient funding. Satellite-based tracking systems need technical developing and maintenance of existing hardware, just like any other technical system, to work properly. Renewal of satellite technology and replacing old satellites with new ones is not cheap. Insufficient funding has already caused aging of the satellites of the GPS-system. The U.S. Government has not been able to replace their old satellites as planned, which has lead to situation in which the amount of required satellites in GPS-system has been feared to drop below its minimum. This problem has been thought as quite a serious risk for the system. [19], [20]

Some of the problems are estimated to be caused by business acquisitions and changes in subcontractors' organizations. Because of the changes in e.g. key personnel in some companies they have not been able to fill their duties in cooperation with the government and in maintenance of satellites and technology [21]. This can be thought as source for a risk of aging of the satellite technology also in the future. Similar problems might face all the satellite-based tracking systems, not only the GPS.

Partially by the reasons above, Europeans have developed their own independent satellite-based tracking system Galileo ran by civilian administration. Russian government has developed their own system, GLONASS, which is developed for global use. Among Russia and USA, also other powerful governments, such as China, Japan and India, are currently developing their own regional or worldwide satellite-based tracking systems.

The GLONASS system has although already faced some problems. The satellite constellation has not been updated as planned because of several technical problems. This has also caused financial pressure for the program. One of the biggest set-back for the GLONASS system occurred in December 2010 when three satellites were destroyed shortly after the launch. The rocket that was supposed to deliver the satellites to the orbit crashed to the Pacific Ocean. [22], [23]

In Japan, the Quasi-Zenith Satellite System (QZSS) is a proposed three-satellite regional time transfer system and enhancement for the Global Positioning System [7]. The first satellite 'Michibiki' was launched on 11 September 2010 [24]. According to [25], fully operational status should be expected by 2013. However, the earthquake and tsunami on 11th March 2011 most likely delays this program, because Japan has so much to do on earth that space operations may have of secondary importance.

These examples are not only possible for the Russian and Japanese systems, but also for every other satellite-based tracking system. These kinds of problems could occur to any other system as well and in the future as there is going to be 5-7 different systems available, unexpected technical problems are likely to affect at least some tracking services. But one has to remember that these problems are hard to forecast and they are dependent from many different matters, financial and technical.

3) Collisions in the Earth's orbit

Earth's orbit already contains thousands of pieces that are being classified as space debris. Experts have estimated that even 300,000 pieces of space debris, with average size of 1-10 cm, might be orbiting the Earth at the moment. The size of these pieces might sound small, but in space their speed can reach such high levels that one of these small pieces of space debris could easily destroy a satellite simply by colliding in to one. [26]

According to NASA's calculations there are also 17,000 man-made objects orbiting the Earth. This figure includes 3,000 still operational satellites from total of 6,000 satellites being sent to the orbit [27]. Most of the pieces of space debris and satellites orbit in the lower-level of the orbit. Satellites used in satellite-based tracking mainly use the mid-level of the orbit, which means that they are still above most of the space debris. At the moment collision between satellite-based tracking satellites and other satellites or space debris is not probable. Still, it is not impossible either.

In lower-level orbit there has already been a collision between two satellites. Both satellites were completely destroyed [28]. The satellites in this collision were owned by USA and Russia. Collision between two satellites is highly unexpectable and improbable, but every collision like the one described above or between satellite and space debris cause the amount of space debris to increase. This naturally increases the risk of new collisions as there would be more uncontrolled debris in the orbit. right after the collision the debris created by it will be very unpredictable and the movement of debris cannot be even estimated. Only after a long period of time, depending on the piece, the movement of the debris can be estimated. This makes it possible for the satellite administrators to try controlling the satellites to avoid collisions. The risk of problems caused by space debris is increasing especially because the debris cannot be taken away from the orbit. [29]

In the future, even more countries can afford investing on their own space programmes and own satellites. They will also have the need for the technological advantages of the satellite-based systems. The attractiveness of own space programmes and satellites is based on the independency; with your own system you can have all the credit from your technological innovations and systems to your own country and you are not dependent on the other countries. When more countries and organizations get interested in space technology, the lower-level orbit will lose its attractiveness because on the congestions and increasing level of space debris. This might lead in to situation, in which new satellites move to mid-level orbit, same level that the satellite-based tracking satellites use, when risks increase also in this level.

Losing one satellite used by the tracking systems would cause only small or even insignificant harm for the reliability of satellite-based tracking systems. This is because most of the time different satellite-based tracking systems have amount of satellites in use that exceeds the minimum requirements of accurate tracking. Although, losing one satellite is extremely expensive and replacing destroyed satellites is very slow process. Physically broken satellites also cause the amount of space debris to increase in mid-level orbit which increases the risk of collisions for other operational satellites. One collision might even cause a chain reaction which would make it even more expensive and difficult to maintain satellites in orbit. This could also affect on the users of satellite-based tracking by accuracy loss or new expenses.

4) Information Security

Information security related vulnerabilities already occur with satellite based tracking systems [30], [31]. Commercial satellite based tracking services are usually built by using commercial telecommunication networks, internet and IT services. The level of information security is not usually known and the user has to be aware if the tracking service is used for tracking sensitive or confidential targets. Location data can be captured by the third party if the data transfer path is insecure or the location data can be stored in insecure place. The system is potential target for denial of service (DOS)-attacks, viruses, worms, pharming, cross scripting, and social engineering too. Modern smart phone have integrated GPS functionality and the user should be aware if the smart phone is used as tracking device. New smart phone operating systems, like iOS by Apple and Android by Google, have security vulnerabilities and they will be interesting targets for the criminals when the number of terminals grows [30], [31]. Lately, there has reported 65 security vulnerabilities for iOS [32] and 88 security vulnerabilities for Android 2.2 [33]. The rising trend of found security vulnerabilities shows that users have to be careful with their smart phones if these will be applied in business critical applications and services.

5) Capacity of mobile networks

Many satellite-based tracking applications rely on commercial telecommunications networks. The quality of networks cannot be guaranteed and it is possible that the tracked object, such as a vehicle, goes outside radio coverage or network is congested in highly populated areas. In international environment, the quality of telecommunication networks may vary in different countries and roaming can cause problems. In the future, many mobile networks can be overloaded due to increased number of customers and cost saving of operators.

6) Unintentional interferences

All existing navigation systems (GPS, GLONASS) and the new ones (Galileo, COMPASS) are using same L1 frequency. The usage of same frequency could cause interference problems if the systems are not designed properly [34].

Other lately reported case handled telecommunication system and GNSS interworking; 4G (LTE) network by LightSquared will cause interference for GPS signal in U.S because they are using almost same frequency. The results of simulation showed that the interference will start at 22.1 km for the aviation receiver and total signal loss occurred at 9.0 km from the transmitter. [35]

7) Intentional interferences

The intentional interference of satellite-based tracking signals causes risks for different kind of end-users. Some of the users might not require constant navigation or tracking services, especially to ensure their security, but some users have the need to have real-time monitoring for their fleet and equipment. Examples of this kind of users are for example Cash-In-Transit-companies and prisoner transports. They need to monitor their vehicles to ensure the safety and security of their staff and cargo or passengers. Jamming the tracking and navigation of these users might give people with criminal intent advantages in their operations. Some robberies have already been made with the aid of jamming devices.

Tracking devices can be interfered in several ways. GPS (like any other satellite navigation system) frequencies are commonly known and therefore easily disturbed. Jamming means blocking the actual tracking signals by generating noise to cover and replace the tracking signals with a special device for this purpose, jammers. The tracking devices cannot interpret the jamming signals and therefore the tracking does not work properly [37]. Intentional jamming does not require very sophisticated equipment. Though illegal to use in most countries, GPS jammers can be bought on the internet for as little as $30 [36]. Similarly, tracking device transmissions are as easily stopped by causing noise to GSM and 3G frequency. More sophisticated way to interrupt tracking transmission is to use a fake base station, when no other signals are disturbed. This makes interference detection much more challenging.

Satellite-based tracking signals can also be "spoofed". Spoofing means feeding false signals to the tracking system in order to have for example the GPS unit to display false information about locations and routes. The tracking device then thinks that it is another place than it actually is. The spoofing is possible because the spoofing device fools the tracking device by sending stronger signals than the actual satellites send from the space. Most of the tracking devices available today accept the false signals as real ones because they are stronger and easier to receive. [37] One way to spoof tracking system is to use fake satellites (so called pseudo-satellites or pseudolites). Instead of jamming, pseudolites imitate satellite signal. Corrupted satellite data causes wrong positioning for tracking devices. [38]

One, theoretical way to prevent tracking is to use electromagnetic pulse (EMP) device. EMP devices are expensive and developed for military use. There are no reports about using any EMP device to disrupt civil tracking systems. [39]

It is very important that all jamming and spoofing devices are being illegalized in every country. Mostly, these devices are designed for criminal intentions and they have very little if any advantages in security and safety. The jamming devices are cheap aids for criminals to be used in many kinds of criminal activities. And the devices may even have unintentional consequences when they are being used. A strong jammer could even affect air traffic and cause danger for many people at the same time.

This technology is being constantly further developed and it is making progress as much as the tracking systems. The signal modulation and frequencies of satellite-based tracking systems are public information and they are used also for building jammers. In the future, this kind of development of jamming and spoofing devices could be expected to be growing trend as there will be more satellite-based tracking systems and new services available. The jamming and spoofing may become a serious problem in the form of concrete safety and security risk. If the jamming devices start causing severe problems, the whole concept of satellite-based tracking systems may end up in unpopularity and unreliability problems, which cause financial problems for the administrators of different systems.

E. Risks of satellite-based tracking business

The use of GPS based tracking devices has been generalized in 21st century. Navigator devices and other GPS based tracking devices have been more available for private users. The reasons for this have clearly been due better availability and cheaper prices and better tracking accuracy. In addition to the equipment itself the growing usage of GPS based tracking services has generated other navigating related businesses.

1) Increasing number of services

The amount of companies providing navigating solutions has grown rapidly while satellite-based navigating equipment has become more popular. These companies mainly provide GPS-based fleet control systems and systems related to logistical security of customers.

GPS-based solutions that are being sold to companies are also being leased, this means that the service provider has significant role even after the product has been delivered and installed. This also means that risks are being related in information security and integrity of tracking information [31] from the service user's point of view. In the current economical situation it is likely that companies buy their navigating services from an outside service provider. When there are more people involved in the navigating production chain, it increases the risk of tracking information to end up in wrong hands. It is likely that this situation will continue to progress to the same way in the near future and satellite-based navigating systems will be the most used mean to navigate. Due this fact, companies will have plenty of tracking information available, which value can't be understated.

Tracking information is valuable and important in two ways. Firstly the information itself and the usage of it, is significantly important to the company using it. On the other hand the personal location information that is contained in the tracking information is very valuable and delicate, due the privacy issues. When the amount of location information is increased in the companies and it is being managed by subcontractors the criminals have more possibilities to get the information they need. Criminals could acquire this location information in numerous ways; some of the possible options could be corruption such as bribing, information thefts and burglaries. Criminals could use this location information in

many ways, from extortion to planning and conducting heist. It is very likely that competition will grow between service providers when new satellite-based navigating systems such as Galileo are being launched. It is likely that this competition will create pressure to save in the costs, so that service pricing will be competitive. Savings in the wrong places could cause serious information security issues to the customer buying those services. On the other hand it could lead to improvement of information security as it could turn to valuable competing advantage. Growing competition in the service provider field also requires more knowledge from the buyer.

If the knowledge about the services and its technical features are poor in the buying organization, it could be possible that wrong kind of systems, services and equipment are being bought; this can also create new risks concerning information security.

2) Private ownership

One possible future scenario for the companies using satellite-based tracking services is that satellite tracking systems would become private. This means that one or more satellite-based tracking systems would be administrated by a private company, which would have only one goal: to get as much profit as possible. One possibility in the future is also that a private company would build its own satellite-based tracking system.

Possible reasons for national or multinational satellite systems to become ran by private companies are several. The GPS-system, administrated by the U.S. government, has faced some serious financial troubles, lack of funding. When this kind of problems occur, it is possible that some government organizations are forced to sell their systems to private funders at least partially. In worst case scenarios the governments are forced to give up the whole system and give its administration to a private company. Other possible reason for the satellite systems becoming private companies is a loss of interest of the government actors. This might be consequence of some new systems in the market, radical changes in legislations nationally or internationally, pressure from the society and disagreements in the administrative organizations or the organizations falling apart.

The risks caused by all this concern financial matters, quality of service and information security. As the main goal for a company is to make profit, the case would be that satellite-based tracking will become paid service. Possible service charges would then be added to all other costs of the user's business and this would naturally make the service, provided e.g. by logistics company, more expensive. In the worst scenario, one big tracking company with administration of all satellite systems would have international monopoly. Also if there were more than just one satellite-based tracking company, the competition between them would most probably cause them to save money in every aspect. This could affect on the service quality and accuracy of the tracking. Private companies could also have different kinds of information security policies, some better, and some worse.

IV. Conclusion

The future will most likely bring multiple new risks to the field of satellite-based tracking. All of them can not be forecasted, but some possibilities have been thought already.

Natural disasters such as solar storms cannot be forecasted reliably; only their possible effects for the society can be estimated in forehand. Current economic situation could cause long term effects on the satellite systems as their budgets might face cuts in the future. Different kind of future conflicts around the globe might have effects to the accuracy and integrity of the systems, as different parties don't want their enemies to use them to their causes. It is possible that the nationally or internationally owned satellite systems are being moved to private corporation ownership. This is a risk for companies using satellite based tracking in their businesses.

As a conclusion, the risks that are likely to face satellite-based tracking are caused by financial, political and natural causes. Because of these risks, all the different end-users of satellite-based tracking need to be updated, both technically and mentally. The availability of different services will most likely increase as new service providers come to the expanding market in the future. Variety of the services is growing and the customer has to use more time and effort to find the best and most reliable alternatives. Keeping one's information up to date is crucial.

References:

[1] Inside GNSS: About GPS. http://www.insidegnss.com/aboutgps

[2] Kämppi, P., Guinness, R., Urpila, T. "Field Testing for Satellite Based Tracking Systems", 61st International Astronautical Congress, Prague, Czech Republic, Sep 2010.

[3] Ohisalo, M., Tiuri, O., Urpila, T., Rajamaki, J,. "Future Risks of Satellite-based Tracking" in Proc. 9th WSEAS International Conference on Applied Electromagnetics, Wireless and Optical Communications (ELECTROSCIENCE '11), Meloneras, Gran Canaria, Canary Islands Spain, March 2011.

[4] SATERISK – Front Page, http://www.saterisk.fi

[5] Viitanen, J., Happonen, M., Patama, P., Rajamäki, J., "Near Border Procedures for Tracking Information", WSEAS TRANSACTIONS ON SYSTEMS, Issue 3, Volume 9, March 2010, pp. 223-232.

[6] Heinonen, S., "Multidimensional Concept of Risks in Horizon Scanning and Futures Thinking", Thinking about the Future - Strategic Anticipation and RAHS, Edited by Tan Hong Ngoh & Hoo Tiang Boon, National Security Coordination Secretariat, Singapore 2008, pp. 53-68.

[7] Takahashi, H., "Japanese Regional Navigation Satellite System 'The JRANS Concept'", Journal of Global Positioning Systems Vol. 3, No. 1-2, 2004, pp. 259-264.

[8] News.com.au, Sun storm to hit with 'force of 100m bombs, 25.8.2010, http://www.news.com.au/ technology/sun-storm-to-hit-with-force-of-100-bombs/story-e6frfro0-1225909999465

[9] Stub, H., Tieteenkuvalehti, Auringossa puhkeaa supermyrsky, 13/2009, pp. 54-59.

[10] Helsingin Sanomat, Nasa pelkää aurinkomyrsky-jen sekoittavan satelliitit, 21.6.2010, http://www.hs.fi/ulkomaat/artikkeli/Nasa%20pelkää%20aurinkomyrskyn%20sekoittavan%20satelliitit/1135257764045

[11] Fox News, Intense Solar Storm Spins Satellite Out of Control, 3.5.2010, http://www.foxnews.com/scitech/2010/05/03/intense-solar-storm-spins-satellite-control/

[12] EU, Satellite navigation: Galileo, 2006, http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/motor_vehicles/interactions_industry_policies/l24205_en.htm

[13] Washington post, NASA budget for 2011 eliminates funds for manned lunar missions, 2010, http://www.washingtonpost.com/wp-dyn/content/article/2010/01/31/AR2010013101058.html?hpid=topnews
[14] Los Angeles Air Force Base, 2009. http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=5325
[15] United States Government, Global Positioning System, 2009. http://www.gps.gov/systems/gps http://www.gps.gov/systems/index.html,
[16] Popular mechanics, China's Space Threat: How Missiles Could Target U.S. Satellites, 2009, http://www.popularmechanics.com/technology/military/satellites/4218443
[17] BBC News, US missile hits toxic satellite, 2008, http://news.bbc.co.uk/2/hi/7254540.stm
[18] United States Air Force, Airmen Upgrade GPS Constellation, 2010, http://www.af.mil/news/story.asp?id=123207262
[19] US Government Accountability Office, GLOBAL POSITIONING SYSTEM-Significant Challenges in Sustaining and Upgrading Widely Used Capabilities, 2009, http://www.gao.gov/new.items/d09325.pdf
[20] GPS World, GPS at risk: Doomsday 2010, 2009, http://www.gpsworld.com/gnss-system/news/gps-risk-doomsday-2010-7092
[21] TidBits, GPS Accuracy Could Start Dropping in 2010, 2009, http://db.tidbits.com/article/10276
[22] Spaceflight now: Proton launch failure dooms Glonass navigation satellites, http://spaceflightnow.com/news/n1012/05proton/
[23] Inside GNSS: On-Orbit Signal Problem Delays Next GLONASS Satellite Launch; Russian Space Agency Investigates, http://www.insidegnss.com/node/1688
[24] Launch Result of the First Quasi-Zenith Satellite 'MICHIBIKI' by H-IIA Launch Vehicle No. 18, press releases, Mitsubishi Heavy Industries, Ltd. & Japan Aerospace Exploration Agency (JAXA), September 2010, http://www.jaxa.jp/press/2010/09/20100911_h2af18_e.html
[25] The System, GPS World Online, November 2007, http://www.gpsworld.com/gnss-system/the-system-november-2007-4187
[26] AFP, Satellite collision threatens space assets, 2009, http://www.google.com/hostednews/afp/articl e / ALeqM5jvfEVRZaKiQ3lkNywl24bowKy9-A
[27] BBC News, Russian and US satellites collide, 2009, http://news.bbc.co.uk/2/hi/7885051.stm
[28] Tekniikka ja Talous, Usan ja venäjän satelliitit törmäsivät – ensimmäinen kiertoratakolari koskaan, 2009, www.tekniikkatalous.fi/tk/avaruus/ article215924.ece
[29] Drexler, K., The Space Debris collision Problem, 2009, http://metamodern.com/2009/ 03/03/the-space-debris-collision-problem/
[30] Kämppi, P., Rajamäki, J., Guinness, R., "Information security in satellite tracking systems", 3rd International Conference on Communication and Information Technology, Athens, Greece, Dec 2009, pp. 153-157.
[31] Kämppi, P., Rajamäki, J., Guinness, R., "Information security risks for satellite tracking", International Journal of Communications, Issue 1, Volume 3, 2009, pp. 9-16.
[32] Apple. 2010. About the security content of iOS 4. Referred on 26.02.2011. http://support.apple.com/kb/HT4225
[33] Kingsley-Hughes. 2010. 88 'High Risk' vulnerabilities discovered in Android 2.2 'Froyo'. Referred on 08.03.2011. http://www.zdnet.com/blog/hardware/88-high-risk-vulnerabilities-discovered-in-android-22-froyo/10217
[34] Parkinson, P., "Conference plenary, Never Lost Again", 61st International Astronautical Congress, Prague, Czech Republic, Sep 2010.
[35] Edwars, L., "New 4G network could cause widespread GPS dead zones", Feb. 23, 2011. Referred on 06.04.2011. http://www.physorg.com/news/2011-02-4g-network-widespread-gps-dead.html
[36] Hambling, D., "GPS chaos: How a $30 box can jam your life", NewScientist 06.03.2011, http://www.newscientist.com/article/dn20202-gps-chaos-how-a-30-box-can-jam-your-life.html?page=1
[37] El-Bakry, H.M., Mastorakis, M., "Design of Anti-GPS for reasons of security"
[38] Happonen, M., Viitanen, J., Kokkonen, P., Ojala, J., Rajamäki, J.,"Jamming detection in the future navigation and tracking systems", In proceedings of the 16th Saint Petersburg International Conference of Integrated Navigation Systems, St. Petersburg, Russia, May 2009, pp. 314-317.
[39] Happonen, M., Recognizing risks of satellite-based tracking, Master's thesis, Laurea University of Applied Sciences, 2010, https://publications.theseus.fi/bitstream/handle/10024/15782/Happonen_Markus.pdf?sequence=1