Swedish Civil Contingencies Agency

Stockholm, 5-6 September 2012

Conference proceedings

International round-table on Extreme space weather: Geomagnetic storms, GNSS disruptions and the impact on vital functions in society

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Swedish Civil Contingencies Agency (MSB)

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Photo credit: cover page and page 14 – www.nasa.gov
Layout: Advant Produktionsbyrå AB
Print: DanagårdLiTHO

Order No. MSB510 - December 2012
ISBN 978-91-7383-307-3

Introduction

Over the past few years there has been a surge of interest in studying the impact from extreme space weather and a number of countries are currently reviewing their planning and preparedness to cope with these risks as part of their national risk assessments. However, despite a rising interest from policymakers, media and also from elected officials, there is still a general tendency to view the risks from space weather as "far-out" – both literally and figuratively.

This is a challenge for all of us who are convinced that the risks from extreme space weather are real and deserve more attention. Extreme solar storms or geomagnetic storms belong to the category of risks that are often called HILP (High Impact Low Probability). Such risks are usually harder to argue for than the ones with less impact and higher probability.

It is also an example of a truly transboundary risk which is very difficult to "box in" within a specific sector. The "ownership" is unclear and the management of impact requires a cross-fertilization of many different communities: space scientists, forecasters, engineers, emergency managers, public and private operators of critical infrastructure etc. These factors may provide some explanation to the relative lack of awareness and concerted international action.

I was myself somewhat amazed the first time I heard one of "the believers" explain why the risks from extreme space weather had to be taken seriously. That was in summer of 2009, when I had the privilege of meeting with the Administrator of FEMA, Mr Craig Fugate, in his office in Washington. We were supposed to discuss community resilience but we ended up having a discussion on geomagnetic storms and solar flares – and after that I was also part of the "community of believers".

That fascinating meeting paved the way for the Euroatlantic workshop on extreme space weather that FEMA and MSB organized together in Boulder, Colorado, in February 2010, "Managing Critical Disasters in the Transatlantic domain – The Case of a Geomagnetic Storm". Colleagues from the European Commission

participated in the event and the Space Weather Prediction Center (SWPC) at NOAA hosted the meeting.

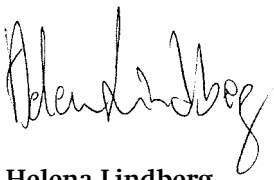
Since then good work has continued also at the European level. Last October, the European Commission organized a Space Weather Awareness Dialogue (SWAD), gathering a select number of experts. The general conclusion from this stock taking event was the need for continued international cooperation to increase knowledge, establish relevant networks and build resilience across national borders. More focused workshops on specific topics were called for to help advance this cause.

I am very happy that this roundtable in Stockholm has been able to add to the important discussions that started in Boulder two years ago and continued at the SWAD last year. The outcome of the Stockholm Roundtable is essentially a result of synergies between the many excellent presentations and interventions that were made by the participants. I was very pleased to be able to welcome such a large group of distinguished contributors from the US (FEMA, NOAA) and the European Commission (JRC, DG ECHO, DG ENTER), European member states, as well as representatives, both public and private, from European organisations (ESA, EUROCONTROL) and a range of different sectors in Sweden and beyond.

Quite a few of the participants had met already in Boulder in 2010. The FEMA Administrator, Mr. Craig Fugate, was with us in spirit.

Hopefully the Stockholm roundtable has moved us a few steps closer to a common Euroatlantic agenda for concrete action. One thing is certain – MSB will continue to promote international and European cooperation for the important task of building resilient societies, able to withstand also the risks from extreme space weather.

Stockholm, October 2012



Helena Lindberg
Director General, MSB

Structure of the event

1. Structure of the event

Director General **Helena Lindberg** welcomed the participants to Stockholm, expressing hopes for an "action-oriented discussion" across the various communities (academic, policy and science) represented at the Roundtable.

The scene was set by key note speeches given by **Dr. Stephan Lechner**, Director of the Institute for the Protection and the Security of Citizens at the European Commission Joint Research Centre (JRC), and **Carole Cameron**, Director of International Affairs at DHS-FEMA. Dr. Bengt Sundelius, Professor and Special adviser at MSB, chaired the introductory session.

Stephan Lechner provided a broad overview of our growing dependency on Global Navigation Satellite Systems (GNSS). He also described the efforts that are taken at national and EU-level to advance our understanding of extreme space weather events and their effects on society. International awareness of extreme space weather has increased over the past few years but "the topic is still too space-oriented". The UK was mentioned as an example of a country where the various expert communities have been successful at collaborating and turning knowledge and awareness into political action. Dr. Lechner advocated a greater focus on creating cross-sectoral platforms at EU and international level to develop a scientific basis for policy making.

Carole Cameron focused her key note remarks on the follow-up of a joint workshop held by FEMA and MSB in 2010 on the management of an extreme space weather event. She described the progress made in a number of areas for Euro-Atlantic cooperation such as "the need to routinely exchange threat and common operating picture with international partners" and "the need to integrate space weather experts and researchers into the emergency management sector". Her conclusion was positive "a lot has happened over the past two years" the lines of communication across the Atlantic have been strengthened but more work remains.

The rest of the program was divided into three consecutive sessions:

Session I ("Early-warning") discussed the strengths and weaknesses of the existing international space weather prediction capability. Measures towards increased international redundancy and resilience were addressed by the panel as well as the potential benefits of developing international standards for measurement and data exchange. The speakers also pointed to the many challenges in conveying alerts that are well received and understood by the end-users.

Session II ("Assessing risks and managing vulnerability") devoted its **first part** of the discussion to the societal impact of space-weather related disruptions in Global Navigation Satellite Systems (GNSS), including the link between GNSS and SCADA systems. The focus was on impact in three critical sectors: electricity supply, air transportation and telecommunications. The vulnerability of the internet was also addressed by one of the key-note speakers as well as the challenges of developing insurance solutions focused on space weather impact.

The **second part** of Session II contained a panel dealing with the integration of risks from extreme space weather into processes for national risk assessment. Examples were given from the Netherlands and Sweden. In this context there was also a discussion – supported by a contribution from the European Commission – on the possibilities for enhanced European and Euroatlantic cooperation, notably in developing and exchanging risk scenarios and non-sensitive data on impact.

Session III ("Knowledge gaps, research, technology and innovations") focused inter alia on the possibilities of making efficient use of the next European Framework Program for Research, Horizon 2020. A priority area for future research and technology development was agreed to be tools and methods for better understanding the impact of space weather on vital societal functions.

Overall conclusions

2. Overall conclusions

- Awareness of the risks from space weather is high among the community of experts but **further work remains to turn this awareness into political action**.
- There are still **major knowledge gaps** when it comes to **understanding the direct and indirect implications of an extreme space weather event on society at large** (cascading effects and interdependencies.) A better understanding of societal impact (based on robust scientific findings) is essential for policy development and decision making.
- **International and EU collaboration** on developing space weather resilience remains **a critical precondition for future progress**.
- There is a need for more **comprehensive platforms for pooling existing knowledge** at various levels (national, European and international).
- There is a need for further work on **methodological frameworks that can be applied and understood across professions and disciplines** – bringing together space and non-space scientists, modellers, forecasters, insurance industry, operators and disaster managers.

Towards a common agenda for action

3. Towards a common agenda for action: Recommendations for Science, Operations and Policy

The Stockholm Roundtable covered many topics but agreement was reached on a number of concrete recommendations for action. These are directed towards the world of science, those engaged in operations and the policy makers. We start with addressing some of the identified knowledge gaps where science may hopefully contribute to improved solutions.

Recommendations for Science:

1. More investments are needed in **S&T programs focused on tools and methods aimed at understanding the societal impact** resulting from extreme space weather events.
2. It is essential to create a **solid link between space research and security research focused on critical infrastructure protection** within the future European Framework Research Program, **Horizon 2020**.
3. There is a particularly strong demand for **scientifically validated worst-case scenarios** providing decision-makers with a better understanding of the fundamental question: "How big is big?" The results of ongoing work in this area (c.f. current project at NASA), needs to be swiftly disseminated to the wider international community of space weather experts and risk managers.
4. More could be done to **match existing European research programs with corresponding programs in the US**. One example would be the European SESAR program (The Single European Sky ATM Research Program) which could be matched with research programs run by NASA focused on the integration of technologies into the Next Generation Air Transportation System (NextGen).
5. Consideration should be made of the need to establish a **thematic work area within the European Reference Network for CIP (ERNCIP) focusing on GNSS and extreme space weather.** ERNCIP, which is managed by the European Commission's Joint

Research Center, links together test facilities, laboratories and research institutes across Europe in different areas.

6. There is a need to **develop standards for testing GNSS receivers against space weather effects**. The purpose is twofold – to understand the performance of GNSS-receivers and to increase the robustness of GNSS-receivers for space weather. The standard should include models for different categories of space weather from normal to extreme.
7. There is a **critical need for investments in international solar monitoring capabilities such as coronagraphs**. The NASA SOHO LASCO coronagraph, used by the SWPC/NOAA in the US, currently provides a unique view of, and advance warning about, potential solar storms. If it should fail before any solution is found on replacement, its absence would significantly degrade international operational space weather forecasts.
8. The **research program "Space Situational Awareness" (SSA), run by the European Space Agency (ESA)** is an important vehicle for future European research in the area of extreme space weather. Sweden (c.f. MSB and the Swedish Armed Forces) should consider a contribution within the SSA program. The SSA program will inter alia contain the development of a coronagraph. The Swedish National Space Board can help coordinate Swedish participation in SSA.

Recommendations for Operations:

1. There is a need to develop methods and models that can help **bridge the communication gap between senders and receivers of alerts and forecasts**. The people who receive the alerts need to understand what **they mean and how to act**. There is work under way aimed at linking alerts to impact assessments (NOAA and ESA reported about ongoing efforts). The good work needs to be shared and further developed internationally together with regional warning centers, emergency management organizations and operators.
2. **The international network for space weather alerts should be further solidified and better integrated with the international emergency management community.** At the direction of the FEMA Administrator, FEMA's daily situation reports now

track space weather events (including geomagnetic storms, solar radiation storms, radio blackouts, the impact on high frequency communications, and sunspot activity). Situation Reports from the European Union Monitoring and Information Center (EU MIC) and NATO's Euro-Atlantic Disaster Response Coordination Centre are shared with FEMA, and FEMA's Daily Situation Reports are shared with European partners through EU MIC. More could however be done in terms of strengthening and connecting the early warning networks at a national, regional and international level.

3. There is a need for a **space weather scenario bank at EU and international level** to draw upon for training and planning.
4. The relationships between space weather scientists, bodies in charge of operational space weather prediction and the emergency management community could be further improved (knowledge building and awareness raising) by developing **systems for liaison and expert exchanges**.

Recommendations for Policy:

1. There is a need for continued efforts to develop **standards and harmonized definitions for international data exchange** (to improve forecasting and modeling).
2. The "**human infrastructure**" needs to be made more robust and prepared for managing extreme space weather events by greater investments in (scenario based) training. More focus should be placed on **introducing extreme space weather within existing training programs and contingency plans** at different levels.
3. The possibility of arranging a **US National Level Exercise on extreme space weather** should be considered. Europe could follow suit by organizing a **pan-European exercise** on the same topic (c.f. previous ones on cyber and on pandemics).
4. There is also a need to **support technological developments** in relation to **GALILEO and GMES** with **related education and training activities**.

5. Investments in training and exercises should be combined with a greater focus on **identifying and sharing lessons learned**, in an international perspective. Within the US, the summary report developed after the 2010 Boulder workshop continues to raise awareness, particularly within the emergency management community.
6. An increasing number of countries are developing national processes **for risk assessment** covering also the risks from extreme space weather. This is an important development. Within the EU, the European Commission is well positioned to provide support to individual member states with data, methodology and the sharing of risk scenarios.
7. There are also good reasons for developing **Euro-Atlantic cooperation in relation to risk assessments on extreme space weather** (possibilities are provided by the current Administrative Arrangement between FEMA and DG ECHO and the cooperation agreement between JRC and NOAA).

Selected key points from the different sessions and panels

4. Selected key points from the different sessions and panels

Session I: Early warning

Chair: *Alois Sieber*
Senior Adviser,
Besozzo, Italy

Contributions by: *William Murtagh*
Program Coordinator,
Space Weather Prediction Center, US/NOAA

Juha-Pekka Luntama
Head of SSA-SWE Segment,
European Space Agency (ESA)

Peter Löfwenberg
POC Climatology and Space Weather,
Swedish Armed Forces

- NOAA SWPC introduced the session by defining the key mission of early-warning: *"Provide the right information .. in the right format .. at the right time … to the right people .. to make the right decision"*.
- On July 23, 2012, there was a solar storm (**the "Far side event"**) that probably could have reach the same magnitdue as the Carrington event in 1859 (G5/Kp9) if it was directed at Earth (G5/Kp9). Luckily the magnetic orientation pointed away from Earth (!!) – if not, the consequences could have been disastrous.
- Despite best efforts the international space weather **forecasting capability remains limited**.
- Examples of **challenges** mentioned:

– There are currently no solar flare warning capabilities. Some positive research results but a long way to go before the space weather community can produce imminent flare warnings.

– Limited forecast/warning capability for solar radiation storms.

- Good/reasonable forecast capabilities for geomagnetic storms but not possible to determine the magnetic direction of a storm.
- No possibilities to forecast a major solar event weeks, months or years in advance – except statistically.

• Examples of **achievements** so far:

- We can detect conditions that are favourable for solar events.
- We can detect solar events when they take place.
- We can improve and confirm the predictions as the event progresses (especially CMEs).

• There was agreement in the panel that ways of maintaining and improving the international space weather prediction capability would be to:

- Secure future resilience in solar monitoring capabilities such as coronagraphs.
- Develop more advanced forecasting models.
- Improve international exchange of data based on common standards.
- Find ways of translating forecasts and alerts into a language better understood by end-users.
- Increase our understanding of the vulnerability and impact of different space weather events on vital societal functions at home and in the context of international missions.

Session II: Assessing risks and managing vulnerabilities

First part of Session II

Chair: *Alois Sieber*
Senior Adviser,
Besozzo, Italy

Contributions by: *Reto Schneider*
Head of Emerging Risk Management,
Swiss Re

Robert Malmgren
Consultant specialized in SCADA security,
Romab

Fredrik Marsten Eklöf
Senior analyst specialized in GNSS vulnerability,
Swedish Defence Research Agency

- A prolonged power blackout is one of the more challenging potential impacts of an extreme space weather event. The impact may be felt across regions and last for days to months. **The impact of such an event goes beyond the scope of insurance and requires collaboration across governments, businesses and society as a whole.**
- An **Insurers' Working Group on Solar Storm Risk has been established** to consider the possible contribution of the insurance sector in managing the consequences of space weather events and to help raise awareness (Swiss Re, Allianz, Lloyds, Munich re, Zurich).
- According to estimates (Swiss Re), a worst case scenario of economic loss from a severe solar storm ("Carrington-type event") – including GIC damage to 10% of transformers in a specific region, total blackout during 3 weeks - amounts to 132 395 mUSD for Europe (163 866 mUSD for US and Canada).
- Loss prevention and emergency measures by governments and the electric power industry (such as shut down/circuit break) are being discussed – but not everywhere and not enough.

- Some of the biggest hurdles to be overcome are:

– Short term cost/benefit thinking in businesses

– Current vulnerabilities are not yet sufficiently stress tested by historical events. Mind-set of denial in the face of major events. Perceptions that **"our power grid is too big to fail"** – at least from a political perspective……

– …..and the financial crisis goes on, government debt is still on the rise and not enough money is invested in infrastructure…

- There is still a considerable lack of awareness in society and among operators in charge of vital societal functions of what the space weather impact may be on systems dependent on GNSS.
- SCADA systems dependent on GNSS are particularly vulnerable to so called **"spoofing attacks"** where fake GNSS senders are being used to manipulate/distort time.
- **Standards for testing GNSS receivers** need to be developed. Such standards will increase our understanding of the performance of GNSS receivers and help reduce the vulnerability of vital systems to the impact from extreme space weather. The standard may include models for several different categories of space weather from normal to extreme.

Impact on Air Transportation

Contributions by: *Emilien Robert*
Navigation and Space Weather Expert,
Eurocontrol

Thomas Allard
Director General,
LFV

- There has been a 45% increase in the number of passengers over the last decade (a doubling since mid 80´s) and air transport will continue to grow.
- **Technological development** in the air transport sector, necessary to reduce costs (air traffic management costs over coming years will be reduced by 50%) means **more automation and more reliance on satellites** (for communication, navigation and surveillance), l**eading to a sharp increase in vulnerability against the consequences from extreme space weather**.

- Just like in other sectors, there are many interdependencies between technical systems resulting in **a wide range of expected and unexpected knock-on effects from space weather disruptions**.
- There is still a great **lack of awareness and understanding of the risks of extreme space weather among key industrial stakeholders**.
- There has not been enough consideration of possible **"double failure scenarios"** such as an ash cloud situation combined with a solar storm.
- There is currently an initiative by the United Nations organization for civil aviation, **ICAO**, to set up a **worldwide system for navigation warnings to airlines and pilots**. This system will use current networks to get information about solar activities.
- The European Organization for the Safety of Air Navigation (EUROCONTROL) has established **a web-based information system (SKYBRARY) on the impact of space weather on aviation**: www.skybrary.aero/index.php/Impact_of_space_weather_on_aviation

Impact on Electricity Supply

Contributions by: *Mikael Odenberg*
Director General,
Svenska Kraftnät (Swedish national grid)

Magnus Ek
Chief Security Officer,
Vattenfall AB

- We have a lot of knowledge about the space weather phenomenon as such but less knowledge about the impact this may have on our developing technical infrastructure. It seems clear that a development of **smart grids will increase our vulnerability to GNSS disruptions**.
- So far the impacts from occurred space weather events on the grid have been manageable – **the concern is for the really big one**. If we end up in a situation where 5-10 transformers fail we are facing serious problems (in Sweden). Some transformers may take 1-2 years to replace!

- **What actions are we prepared to take the day we get an alert for a really extreme event? Shall we close down the grid for preventive purposes? How will that decision be made?**
- As long as shut-downs are planned and coordinated the process is manageable but uncontrolled developments would provide a major challenge. **It is not only the process of shutting down the grid – the start-up after a long shut-down is another area of concern.**
- More back-up equipment is needed and higher demands should be placed on new equipment (e.g. robustness against GIC)
- The challenges of extreme space weather are not yet on the political agenda in many countries, Sweden is an example. **It is only when it becomes a priority at the political level that operators in various sectors will start dealing with these difficult questions.**

Impact on Telecommunications and the Internet

Contributions by: *Per-Olof Hedekvist*
SP Technical Research Institute of Sweden
Measurement Technology

Ove Landberg
Head of Section,
the Swedish Post and Telecom Authority (PTS)

Patrik Fältström
Head of Research and Development,
Netnod

- **Most of the possible effects of extreme space weather events on telecommunications are indirect and related to power supply disruptions and GNSS disruptions.**
- Power supply disruptions will impact access networks within hours, not days. National GSM networks can typically tolerate power supply failures of around 2-3 hours (fixed networks 6-8 hours). Limiting factors from a preparedness perspective are a lack of mobile power generators and transportation and fuel. It is **necessary that telecom operators make sure they have adequate service level agreements with power suppliers**.

- In terms of **internet vulnerability the current development towards higher speed transmission and more players involved, places greater demands on synchronized (GNSS dependent) timestamps**.
- In Sweden there is ongoing work to establish a **GNSS independent source for time and information synchronization in communication networks** (based on atomic clocks). The research and development is carried out by SP Technical Research Institute of Sweden. There are plans to develop the system in a Nordic context and there is increasing interest from European countries.

Second part of Session II

Chair: *Alois Sieber*
Senior Adviser
Besozzo, Italy

Contributions by: *Ian Clarke*
Head of Unit,
DG ECHO, European Commission

Maaike van Tuyll
Deputy programme manager Threats and Capabilities, National Security Directorate, Ministry of Security and Justice, the Netherlands

Kristina Westerdahl
Principal Analyst
MSB

- **Data and information on the risks from extreme space weather is fragmented across governments and the private sector and still largely unavailable to decision-makers and at-risk populations.**
- **A positive trend is that the risks from extreme space weather are increasingly included in national risk assessments.** National processes for risk assessment provide important vehicles for coherence and cross-sectoral coordination. In the UK the risk from space weather was added to the National Risk Register in 2011 and Norway included space weather in its *Nasjonal sårbarhets och beredskapsrapport* (NSBR) earlier this year.

In **the Netherlands** the impact of space weather is considered as part of the work underpinning the National Safety and Security Strategy. **Sweden** is currently dealing with a risk scenario involving GNSS disruptions as part of its national risk assessment and will develop further work on scenarios based on space weather impacts.

- The **Global Risks Report 2012 presented by the World Economic Forum** identified vulnerability to geomagnetic storms as one of 50 key risks.
- **At the EU-level, the Commission (DG ECHO) has developed guidelines for national risk assessment and is also working to finalise an overview of the major risks the Union is facing** (to be ready in 2013) – **including the risk from extreme space weather.** The EU risk overview has a number of purposes:
  - identify areas where European cooperation may prove more effective than individual member states acting alone and inform policy makers of risks where further action is needed.
  - provide information on longer-term EU strategies and policies such as the 2013 EU climate adaptation strategy, Security Health Initiative, EU Internal security strategy etc, to help orient EU financial instruments.
  - provide generic information to inform the development of contingency planning at EU and national level within the framework of the EU Civil Protection Mechanism;
  - initiate the process towards developing a comprehensive risk/threat assessment envisaged as part of the implementation of the Solidarity Clause (article 222 TFEU) and contributing to a coherent risk management policy.

Session III: Knowledge gaps, research, technology and innovations

Chair: Lars Jernbäcker
Vice President, Head of Business development,
Civil Security, SAAB

Contributions by: *Mats Ljungqvist*
Space Research and Development,
DG Enterprise and Industry,
European Commission

Mats Olofsson
Head of Research,
Swedish Armed Forces

Juha-Pekka Luntama
Head of SSA-SWE Segment,
European Space Agency (ESA)

Johan Köhler
Science Officer,
Swedish National Space Board (SNSB)

Lars Jernbäcker
Vice President, Head of Business development,
Civil Security, SAAB

- There are **still many unknowns in solar physics** (e.g. still not enough knowledge of when active regions may flare or how big the flare may be). Critical **space borne observations have to be ensured** (e.g. CMEs, solar wind). There is also a need to improve data availability through enhanced international ground based observation networks and the development of standards for data exchange.
- However, the **need for more/new knowledge is possibly even more urgent when it comes to understanding the impact of space weather on vital societal functions – at home - and in international missions**. There is a strong demand for **scientifically validated worst-case scenarios** providing decision-makers with a better understanding of the fundamental question: **"How big is big?"**

- Consideration should be made of the establishment of a **thematic work area within the European Reference Network for CIP (ERNCIP) focusing on GNSS and extreme space weather.** ERNCIP, which is managed by the European Commission's Joint Research Center, links together test facilities, laboratories and research institutes across Europe in different areas.
- The future European Framework Research Program, **Horizon 2020, can be a significant driver for innovation** but it is essential that a **solid link is created between programs focused on space research and those on security research, notably in the area of critical infrastructure protection.**
- The **research program "Space Situational Awareness" (SSA), run by the European Space Agency (ESA)** is an important vehicle for future European research on extreme space weather. Sweden (c.f. MSB and the Swedish Armed Forces) should consider a contribution within the SSA program. The SSA program will inter alia contain the development of a **coronagraph**. The Swedish National Space Board can help coordinate Swedish participation in SSA.
- **A catalogue of "space weather assets" in Europe has been established by the European Space Agency (ESA)** (e.g. sensors on ground and on spacecraft; web portals; capacity for alert/report/forecast; data archive; networks etc.) – over 400 space weather assets have so far been identified and the catalogue is still not complete.
- **Swedish industry should be able to benefit from an increased attention to space weather issues** as a result of its skills' profile (e.g. well renowned communication technology research and atmospheric science research) and good reputation.

Next steps

5. Next Steps

This Stockholm round-table has identified a wide range of knowledge gaps but has also found agreement on a number of recommendations, providing a common agenda for action and a way ahead. Through joint international efforts in science and policy, we can develop new knowledge, new methods, models and instruments that will help us reduce existing vulnerabilities and stand more ready to cope with the potentially devastating impacts of extreme space weather. Any national measures that are taken over the coming years will need to consider the wider context of European and Euro-Atlantic cooperation.

It was suggested by several speakers that this round table should be followed in due time by a "review" conference, where an inventory of accomplishments could be made. Often the implementation of well understood and agreed upon solutions to security and safety matters is postponed or dismissed as other urgent policy matters appear. To avoid falling into this trap of neglect, we urge a systematic review within two years of the recommendations from this event. The work has just begun.

Annexes

6. Annexes

References

This Annex lists some important web pages.

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Swedish Civil Contingencies Agency (MSB)
S-651 81 Karlstad Phone +46 (0)771-240 240 www.msb.se/en
Order No. MSB510 - December 2012 ISBN 978-91-7383-307-3