

TRUSTWORTHY SMART AUTONOMOUS SYSTEMS-OF-SYSTEMS – RESILIENT TECHNOLOGY, ECONOMY AND SOCIETY

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Keywords

Smart Systems, Autonomous Systems, Systems-of-Systems, Machine Ethics, Society 5.0, Artificial Intelligence, Trustworthiness, Standardization, Digitalization, Smart Production, Green Deal, UN Sustainable Development Goals

Abstract

Smart and (partially) autonomous systems are today's drivers of innovation and economic respectively societal disruptive changes: in all industrial and social areas highly automated or autonomous intelligent systems are taking over tasks and services – and maybe, one day, control of our lives. This is a considerable risk to democracy, human independence and human rights, raising ethical questions. However, conventional technologies have also an impact, particularly on excessive exploitation of natural resources, climate change and inequality in global economy and society.

The concept of circular economy became a focus when thinking about a more sustainable future. We are now seeing many communities and businesses adopt novel approaches based on circularity. European policy has reacted to the challenges of climate change and environmental footprint reduction particularly in context of production, transport, farming and large urban agglomerations – smartness (intelligence) is not only addressing well-being, assisted living and comfort of citizens (keyword “Society 5.0”), but even more sustainability goals in the long term. The European Green Deal is a commitment to future generations, while the European Green Cities movement addresses many of the UN Sustainable Development Goals and manages a network of cities for collaboration and experience exchange by developing innovative projects.

1. Introduction – Smart and Autonomous Systems

Smart (intelligent) systems, forming together systems-of-systems with sometimes unexpected emergent properties through their interactions and impact on our lives and behaviours, are today's drivers of innovation and leading to disruptive changes in all industrial, economic and social areas. Therefore, our society is facing many challenges – upcoming crisis in many respects, e.g. the climate crisis, the Covid-19 (Corona) crises, and economic as well as social crisis impacts in the future. We have exploited our natural resources in a ruthless manner often just for short term profits and benefits

of a few. This situation is encompassed by an enormous progress in technology, particularly in electronic systems and materials. Smart systems are already everywhere –but integrated into “super-smart systems-of-systems” with advanced algorithms, artificial intelligence and “big data” in the background.

The impact of Smart Systems and Systems-of-Systems on technology evolution, society and economy is enormous, sharing positive as well as negative expectations as a basis for critical discussion. Particular focus is on the evolutionary development towards integrated large and complex system-of-systems cluster applications, e.g. Smart Cities, Smart Farming, holistic production and mobility solutions (e.g. beyond autonomous vehicles towards optimized shared multi-modal mobility and logistics solutions as a service) overcoming the boundaries of single isolated “systems of interest”. The main questions are:

- how to develop intelligent, interconnected cyber-physical systems of systems, the underlying infrastructure (IoT, smart wireless connectivity, AI ecosystem), so that we can guarantee trustworthiness and high acceptance by the citizens,
- how can digital economy systems support a resilient, sustainable and ethically aligned, human-centered society,
- how can we, the people, manage the disruptive changes to be expected.

In a digitalized world, safety and security are well established properties, facilitated by standards, qualification/verification techniques and methods. Highly automated systems are challenging beyond the well-established techniques and methods – they have to react in a reasonable manner on unpredictable situations and environments, to take autonomous decisions based on high-level and (even) ethical principles, situation awareness, perception, scene understanding, Artificial Intelligence, Big data, IoT - these are just a few key words.

Even the attacks on human rights, freedom and independence are now much “smarter”, and most of us are often not aware of the degree of surveillance and control, even in our democracies in the so-called “Western World”.

This will impact considerably our lives and lifestyle, and, as a consequence, we will have to face the new challenges, opportunities and risks. Not to forget the economic risks – recent crisis like Covid-19 lock-downs have demonstrated even our economic vulnerability because of the dependency on worldwide functioning supply chains.

The technological basis is laid by IoT (human – smart devices interaction and communication) and IIoT (IoT in industrial context, machine-to-machine communication) as infrastructure (connectivity), and CPS (Cyber-physical Systems) as “things” or “devices”. But smartness is more – it means intelligence, cognitive systems and technology, machine learning and artificial intelligence, security, big data and cloud connectivity, involving many domains of everyday life and digital transformation of our world.

With respect to safety, cybersecurity, privacy, and data sovereignty, the new “cognitive technologies” are a severe concern for specialists, politicians and citizens, and raise severe ethical and societal concerns, and dependency on these technologies in a networked world is an additional concern now.

For our future it is most important now to strive for a “resilient society” and a “sustainable economy”, both relying on each other. Such a strategy will cope with the challenges particularly by the of the crises mentioned before – climate, pandemic and economic risks, stability of society and long-term survival and peace.

2. European Efforts towards Digitalization

The digital transformation of European business and society is a major goal of the EC. EC Growth, the DG (Directorate General) for Internal Market, Industry, Entrepreneurship and SMEs, considers digital transformation as a key element for European growth, because Europe can build on its strength in traditional sectors and can take up the potential and challenges of advanced digital technologies. Technologies considered in this context are IoT, big data, advanced manufacturing, robotics, 3D printing, blockchain technologies and artificial intelligence (see European Commission, 2018 - 2020).

The initiative “Digitizing European Industry” targets to meet Europe’s needs to join forces under a common strategy that takes digitalization of the EU's economy forward in order to unlock the full potential of the 4th industrial revolution. The pillars of this initiative are (see Figure 1):



Figure 1: Pillars of the European Initiative “Digitizing European Industry”

(Source: <https://ec.europa.eu/digital-single-market/en/pillars-digitising-european-industry-initiative>)

In the booklet “My agenda for Europe” of Ursula von der Leyen, the new President of the European Commission, is one chapter dedicated to “A Europe fit for the digital age”. It focuses on AI, IoT, 5G, and ethical and human implications of these technologies, empowering people through education and skills, and on protecting ourselves with respect to the risks of these technologies.

Research is a key element to drive digitalization forward. On European level, organizations like AIOTI [AIOTI], the Alliance for Internet of Things Innovation, which takes care of the IoT aspects in 13 Working Groups, or the industrial associations ARTEMIS [ARTEMIS] (Advanced Research and Technology on Embedded Intelligent Systems), EPoSS [EPoSS] (European Technology Platform for Smart systems Integration) and AENEAS (Association for European Nano-Electronics Activities), which are the private partners in the ECSEL Joint Undertaking, a European PPP within Horizon 2020 (Public-Private Partnership) with an industry-oriented Research Program, and other PPPs, take care of further development of research, standardization and promotion of these topics, together with the European Commission and national funding authorities. China is already keeping up with Europe, US and Japan, e.g. with its AI initiative and strategy.

But it is not only economics and competitiveness of European industry – the recently announced “Green Deal” as basis and justification for the upcoming huge efforts are targeting at “Resilience” and “Sustainability” in all technology-driven areas, like manufacturing, mobility, public and industrial administration, particularly considering also societal and ethical aspects.

Additionally, DG Growth delivers an annual report on standardization, e.g. the “Rolling Plan on ICT Standardization”, which includes most of the relevant areas in this paper’s context and is a key pillar in Digitalization, and have started a Joint Initiative on Standardization (JIS) http://ec.europa.eu/growth/single-market/europeanstandards/notification-system_en, although they do primarily consider the European SDOs (Standardization Organizations, ESOs) CEN, CENELEC and ETSI. The same is done by the international standardization organizations ISO and IEC, particularly in their Joint Technical Committee JTC1 (Information Technology), which cover all these topics of “Joint interest”, particularly IoT (SC41), AI (SC42) and Security (SC27) and Software and Systems engineering (SC7).

The straightforward goal of these efforts is to have advanced technologies in ICT end ECS (Electronic components and systems) the enable a sustainable and resilient society in the economic and human factors and well-being sense. As examples like the movement of “Resilient Cities” and “Sustainable Growth” show, these technologies are a chance to overcome current waste of resources and to optimize resource usage, recycling and reuse sustainable production not only in industry but also in agriculture (smart farming, in large cities even “vertical farming” in an until now unseen performance making large population agglomerates less vulnerable to supply risks in case of a crisis), mobility, work spaces and living spaces (“smart buildings”, “smart homes”). “Business resilience” is also a key objective, e.g. the COVID-19 impact on global service delivery models, as several studies have described (SSON-Study “Reality Bites – Impact of COVID-19 on Global Service Delivery Models”).

In a publication “Why European companies need to complete the digital transformation to remain viable and competitive”, this crisis is considered as a “turbo” to advance faster in our digitalization – to become more resilient and sustainable as economy and society.

The Corona-crisis is looked at as a “disruptive force and digitalization turbo” (citation):

“Breakthrough for digitalization”, “How the virus makes digitalization move forward” or “Corona makes the Internet a matter of course” – this is how the headlines of articles describing the effects of the coronavirus on the digitalization of various areas of life are currently read.

On the other hand, human freedom, independence and privacy is for sure endangered, as well as too much dependency on technologies you have not nearby access to concerning maintenance and update.

Examples how AI can influence our job situation is demonstrated by measures of some large companies, and even public organizations, particularly by biased training datasets (taken from newsletters):

- Microsoft replaces journalists by AI systems (for MSN-website News)
- Public unemployment service uses AI algorithms to select clients: elder women skipped out of the search for jobs (without individual check of qualification)
- Racist decisions by AI systems (court, police, gender issues)

Therefore, we have to look not only at system properties like safety, security or privacy, but also on other aspects, how we can “TRUST” these technologies.

3. The UN Sustainability Goals and the European Green Deal

On a historic UN summit September 2015, the United Nations General Assembly set the “2030 Agenda for Sustainable Development”, which came into force on 1 January 2016. The world leaders adopted the [17 Sustainable Development Goals \(SDGs\)](#). This is a commitment for the next fifteen years, to fight hunger, disease, poverty, inequality, and climate change which are real problems that affect millions of people every day, ensuring (hopefully) that no one is left behind.

As easy as these issues are to identify, actually solving them requires a global effort, cooperation, and an understanding that everyone can play a part in moving us forward. These 17 GSDs (also called “Global Goals”) are a collection of interconnected goals designed to give all of us on our planet a better future, with hundreds of targets and measurement indicators geared toward a date of 2030. The goals were created with businesses in mind, providing a path – what some people refer to as a “Pathway for Humanity” — for any business to harness their power by directing their efforts toward specific global objectives. The reference in the bibliography at the end of this article is downloadable for everybody – it is a booklet describing in a concise manner these 17 goals. More details with further links can be found on <https://sdgs.un.org/goals>.

The goals themselves to be simple and direct, but powerful, ranging from ending poverty to building sustainable cities. Technologies are key to realize the most important goals for a still growing world population under pressures like resource exploitation and climate change. An overview is provided in Figure 2. The Global Goals are:

SDG 1: No Poverty	SDG 2: Zero Hunger
SDG 3: Good Health and Well-being	SDG 4: Quality Education
SDG 5: Gender Equality	SDG 6: Clean Water and Sanitation
SDG 7: Affordable and Clean Energy	SDG 8: Decent Work and Economic Growth
SDG 9: Industry, Innovation & Infrastructure	SDG 10: Reduced Inequalities
SDG 11: Sustainable Cities and Communities	SDG 12: Responsible Consumption & Production
SDG 13: Climate Action	SDG 14: Life Below Water
SDG 15: Life on Land	SDG 16: Peace, Justice and Strong Institutions
SDG 17: Partnerships for the Goals	

To monitor and track progress in achieving results towards the SDGS (Sustainable Development Goals), the UN has created a global initiative “Sustainable Development Solutions Network” (<https://www.unsdsn.org/sdg-index-and-monitoring>). The SDSN methodology (sound metrics, statistical methods, identification of gaps etc.) was audited by the European JRC (Joint Research Center) in July 2019, the results of which are available as a report (see References).

Several regions of the world have developed related reports, e.g. the *2020 Europe Sustainable Development Report* (ESDR 2020) builds on the methodology of the annual *Sustainable Development Report*, including SDG Index and Dashboards, issued by the SDSN and Bertelsmann Foundation.

The European Green Deal

The European Commission has particularly addressed the challenge of Climate Change and Climate Action. In „COM(2019) 640 final“, a communication of the European Commission to the European institutions (European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions) on “The European Green Deal”, the declared goal is a Europe “Striving to be the first climate-neutral continent”. It is an ambitious commitment to future generations, identifying

“Climate change and environmental degradation as an existential threat to Europe and the world”.



Figure 2: The UN 17 Sustainable Development Goals (“Global Goals”)
 (Source: <http://greencities.eu/about>)

To overcome these challenges, the **European Green Deal** will transform the EU into a modern, resource-efficient and competitive economy, ensuring:

- no net emissions of greenhouse gases by 2050
- economic growth decoupled from resource use
- no person and no place left behind

The European Green Deal has an [action plan](https://eur-lex.europa.eu/legal-content/EN/TXT) (<https://eur-lex.europa.eu/legal-content/EN/TXT>) to

- boost the efficient use of resources by moving to a clean, circular economy
- restore bio-diversity and cut pollution

The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition.

The EU aims to be climate neutral in 2050. Reaching this target will require action by all sectors of our economy, including

- investing in environmentally-friendly technologies
- supporting industry to innovate
- rolling out cleaner, cheaper and healthier forms of private and public transport
- decarbonising the energy sector
- ensuring buildings are more energy efficient
- working with international partners to improve global environmental standards

The EU will also provide financial support and technical assistance to help those that are most affected by the move towards the green economy. This is called the [Just Transition Mechanism](#). It will help mobilize at least €100 billion over the period 2021-2027 in the most affected regions. A most important part of this huge effort is dedicated to research towards “clean green technologies” to be developed and implemented throughout Europe, converting economy and society.

The European Green (Sustainable, Resilient, Circular) Cities Movement

Following the ideas and concepts of the UN Sustainable Development Goals and the European Green Deal particularly in context of urban agglomerations, where worldwide the large majority of people will live, the “European Green Cities” organization was founded in Europe.

European Green Cities is a non-profit organization, founded in 1988, that strive to help alleviate the climate crisis, by developing CO₂-neutral cities and neighborhoods across Europe. The mission is to contribute to the development of green cities and buildings in a sustainable Europe, by supporting the projects with their know-how.

“European Green Cities” helps to alleviate the climate crisis by supporting municipalities and citizen-organizations to develop innovative projects within energy transition and mobility, facilitate stakeholder processes, carry out analysis, implementation of best practice, training in sustainable urban development and dissemination.

The organization initiates new project proposals and EU-applications, and help put the team of partners, cities, organizations, companies and consultants together.

European Green Cities also manages a network of cities to ensure collaboration and share knowledge across borders. Concrete examples and current projects can be found at <http://greencities.eu/projects>.

SDGs and holistic urban development

In European Green Cities we mainly support The UN Sustainable Development Goals no 3, 7, 9, 11, 13 and 17. The UN SDGs are interconnected, and thereby improving one of the goals often affect several of the others positively. But it is important to keep in mind that one battle at a time is more efficient, that trying to target everything at once, therefore we help cities create a baseline methodology, when they want to work with the SDG’s proactively.

- Targeting the UN 17 Sustainable Development Goals
- Baseline development
- Long term planning
- Creating synergies through interdisciplinary knowledge

Mobility and inclusive environments

European Green Cities are supporting great mobility for all users - especially children and women. Providing space for user groups that often are dependent on walking or cycling, make the city accessible for everybody, and support the green transition towards a more CO₂-neutral mobility system. Further they support fossil free car-use.

- Mobility plans
- Cycling analysis and strategic solutions
- Gender sensitive urban planning
- Solar powered E-mobility and charging infrastructure

Smart buildings and energy efficiency

European Green Cities have over the years contributed to making façade renovations to support lower energy consumption and better living environments. We work to improve the building stock of social housing by contributing with our proficient knowledge from a vast variety of renovation projects across Europe.

- Fjernvarme
- Knowledge on facade renovations and isolation
- Support better housing for
- Eliminating energy-poverty

Communication and stakeholder engagement

European Green Cities help stakeholders to include optimization and development of energy efficiency, energy production, mobility, health, education, fair democracy, recycling management, job creation, gender equality, smart grids, climate adaptation and biodiversity.

- Workshops and Community engagement
- Stakeholder processes
- Develop interdisciplinary understanding
- Webpage and newsletter design and management

EU Funding and project management

We support the cities, by offering cooperation in the first phases of project development, finding EU-funding and putting together a team, and eventually implementation, dissemination and project management.

- Fundraising
- EU-applications and processes
- Strong network of European cooperation partners
- Project management
- EU-policies and agendas

To ensure knowledge sharing across Europe, the organization also manages the non-profit **European Green Cities Network**. The network consists of municipalities, social housing organizations, institutions, companies and universities from more than 19 countries.

4. Trustworthiness of Smart Systems and Systems-of-Systems

Safety and security are well established properties, facilitated by standards, qualification/ verification techniques and methods. Highly automated systems are challenging beyond the well-established techniques and methods – they have to react in a reasonable manner on unpredictable situations and environments, to take autonomous decisions based on high-level and (even) ethical principles, situation awareness, perception, and scene understanding.

With respect to “Resilience” and “Sustainability”, ISO/IEC JTC1 standardization sub-committees SC7, SC41 and SC42 join forces as enablers by creating the adapted system property

“Trustworthiness”, leading beyond just safety and (cyber-)security in the established definitions. This is particularly of importance if we look at the requirements for a resilient, sustainable society and economy – which goes beyond the classical technical requirements.

Trust means, according to the Joint Technical Committee 1 on Information Technology of ISO and IEC <ISO/IEC 25010:2011(en)>:

- “... the degree to which a user or other stakeholder has confidence that a product or system will behave as intended” (*ISO/IEC 25010, Systems and software engineering*),

And *Trustworthiness* is

- “*the ability to meet stakeholders’ expectations in a verifiable way*”, which includes, e.g. *reliability, availability, resilience, security, privacy, safety, accountability, transparency, integrity, authenticity, quality, usability, but also societal and ethical properties.*

Resilience, in a technical sense (there are psychological definitions also), may be defined as:

- “... *the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation. Threats and challenges for services can range from simple misconfiguration over large scale natural disasters to targeted attacks.*” (*Wikipedia, networks*)

The societal and political part of resilience and sustainability is defined by the public stakeholders’ interests who provide the framework for a resilient and sustainable implementation (“Jurisdiction”).

Trustworthy systems-of-systems should support a sustainable economy (“EC Green Deal”, meeting the “Grand Challenges” of the “UN Sustainable Development Goals”) for the benefit of all people and not of a few only, while preserving human rights and ethical principles as far as possible. The goal could be a “Society 5.0” as reported in last years already in this session, but under consideration of the potential risks and respecting fair reasonable regional habits and backgrounds.

They should make society resilient against upcoming challenges like climate change, food shortage, increasing population and, on the other hand, to support the inclusion of the growing number of elder people or people with special needs. Resilience of a society means also to cope with critical shorter-term challenges (e.g. the Corona virus crisis), by smart robotics, digitalization and technology support in our case.

5. Machine Ethics - Ethics Guidelines

The impending highly automated and autonomous systems enabled by artificial intelligence (AI) bring with them new challenges and risks. Placing too much trust in, or misusing, machines that make decisions is risky, and the legalities are complex in terms of liability and responsibility. Autonomous systems can be grouped into three broad categories: technical systems that make decisions in “no win” hazardous situations (vehicles in traffic, collaborating robots); decision support systems in governance applications (administration, government, court, staff acquisition, etc.), which may lead to unfair decisions for humans and society; and systems that are open to deliberate misuse by providing information that can’t be proven to be true or fake, potentially influencing elections, public opinion or legal processes to an extent unknown before. These risks cannot be easily countered by conventional methods.

Of course, there have long been risks associated with technology, with the potential for the dissemination of misinformation, failing algorithms and deliberate deception, but until recently the methodology at least allowed analysis and assessment of the predictable and deterministic algorithms behind the technology. We are now facing a completely different challenge – the age of highly

automated and autonomous systems, artificial intelligence (AI) and decision making, whereby human decisions are made by machines through methods such as deep (machine) learning, which are neither “explainable”, nor be based on fair, unbiased training sets.

Public acceptance of highly automated and autonomous systems relies on trust in these systems. This is not just a technical issue (which have been discussed in the chapters before), but also an ethical one, with technology having “big brother” potential and other possible problems as foreseen in science fiction, e.g., Isaac Asimov’s “Three Laws of Robotics”. Asimov’s laws seem reasonable and complete, but although they were complemented by an overarching “Zeroth law” (“A robot may not, through inaction, allow humanity to come to harm”), it has been demonstrated (even by Asimov himself) that realistic situations may result in unresolvable conflicts for a robot just because of adhering to this law.

AI technology is being implemented in automated driving, collaborative robots in the workspace, assistive robotic systems, highly automated production, and in management and decision systems in the medical and public service areas, the military, and many other fields. The EC, the European Parliament, the UN, many informatics and computer associations, and standardisation groups, the German Ethics Commission for Automated Driving, NGOs, and others, have created guidelines or even certificates for trustworthiness of highly automated systems, AI-systems, cognitive decision systems, automated vehicles, robotic systems, ethically aligned design, and the like (see references). A new science of “robot psychology” has evolved, that studies the interrelationship of human-robot collaboration and human wellbeing.

It seems that the question “Is it possible to create practical laws of robotics which can guarantee a safe, conflict free and peaceful co-existence between robots and humans?” cannot be given a definitive answer that is valid in all foreseeable situations. Even in Asimov’s stories, robots had to decide which type of risk of harm is acceptable (e.g. autonomous robotic surgeon).

These robotic laws were written in 1942, when robots were androids and just relatively simple “slaves” for humans, not the highly complex robots that are conceivable today. And what about a robot developed for an army? And who is defined as a “human being” (from history we know that sometimes a certain group of people is not considered as equally human, e.g. genocide)? For this, we have to look at the humans behind the AI and robots. And this only partially covers the aspects of “machine decision making” and “machine ethics”, referred to in the abstract.

One initiative attempting to cover the principles for system designers and developers is the IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems (AI/AS) (April 2016, with a document 2019). It not only identifies and recommends ideas for standards projects focused on prioritizing ethical considerations in AI/AS (i.e., machine/computer decision making), but also proposes a certificate for “ethically aligned design”. The basic concept states:

“Ultimately, our goal should be eudaimonia, a practice elucidated by Aristotle that defines human well-being, both at the individual and collective level, as the highest virtue for a society.... honouring holistic definitions of societal prosperity is essential versus pursuing one-dimensional goals of increased productivity or gross domestic product (GDP). Autonomous and intelligent systems should prioritize and have as their goal the explicit honouring of our inalienable fundamental rights and dignity as well as the increase of human flourishing and environmental sustainability. The goal of “The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems” is that Ethically Aligned Design will provide pragmatic and directional insights and recommendations, serving as a key reference for the work of technologists, educators and policymakers in the coming years.”

Many standardization groups, the EC HLEG group document, and the German Ethics Commission on Automated and Connected Driving, provide a set of recommendations for decision making, placing human rights, independence and wellbeing in the centre, independent of economic or demographic attributes, such as age and race. But within the Trustworthiness groups on ethics and governance in ISO/IEC JTC1 SC41 (IoT) and SC42 (AI), the international discussion revealed that even the definition of (individual) human rights differs among cultures and different legal systems.

6. Conclusions

The technologically oriented funding organizations and the EC have a very positive approach and high expectations concerning the benefits of digitisation of economy, industry and society. The “Green Deal” programme and the human implications of these technologies, empowering people through education and skills, and on protecting against the risks of these technologies, are targeting resilience and sustainability of society and economy. However, we should be aware that many of the achievements could be used against us as well (and some research projects consider this fact already) or lead to wrong decisions because of badly trained or biased AI systems.

The final question is: Will technologies of the fourth/fifth industrial revolution (e.g. IoT, Big Data, Artificial Intelligence, Connectivity, robots) enabling disruptive developments (evolutionary or revolutionary), lead to a resilient, sustainable and sharing society, to “well-being for all”, if based on higher ethical values?

Acknowledgements

Part of the work received funding from the EC from the EU Horizon 2020 Programme, the ECSEL Joint Undertaking and the partners’ national funding authorities (in Austria FFG (Austrian Research Promotion Agency) on behalf of BMK, The Federal Ministry of Climate Action, Environment, Mobility, Innovation and Technology (BMK)) Transport, Innovation and Technology) - (Grant agreements n° 737459-2 (Productive4.0) and n° 737469-2 (AutoDrive), and SECREDAS (783119), iDev40 (783163), AfarCloud (783221) and AI4CSM (101007326-2)).

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