26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

Testing of Autonomous Systems

Challenges and Current State-of-the-Art

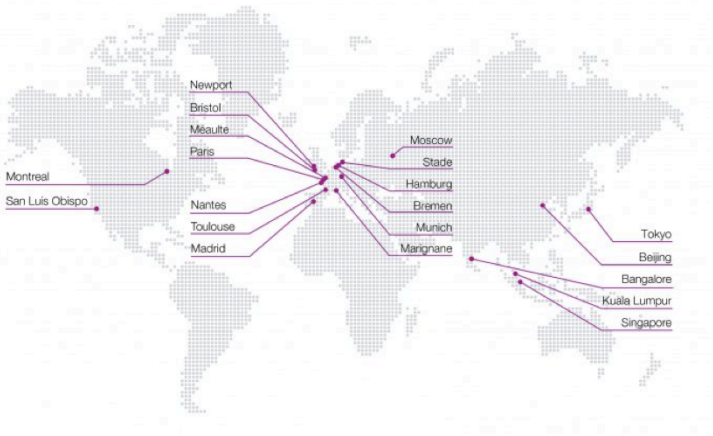
Philipp Helle, Airbus Group Innovations
Wladimir Schamai, Airbus Group Innovations
Carsten Strobel, Airbus Group Innovations

AIRBUS GROUP …at a glance

Airbus Group Innovations

Key figures

- Over 800 Researchers, Scientists, Engineers worldwide
- 20 sites around the world
- Located in 12 countries
- More than 100 new patent applications every year



Outline

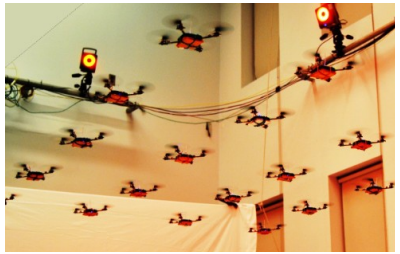
26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

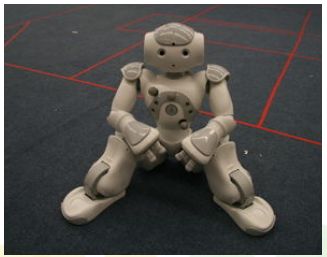
- Autonomous Systems
- Testing Autonomous Systems
- “Things to do”

26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

AUTONOMOUS SYSTEMS

Autonomous systems



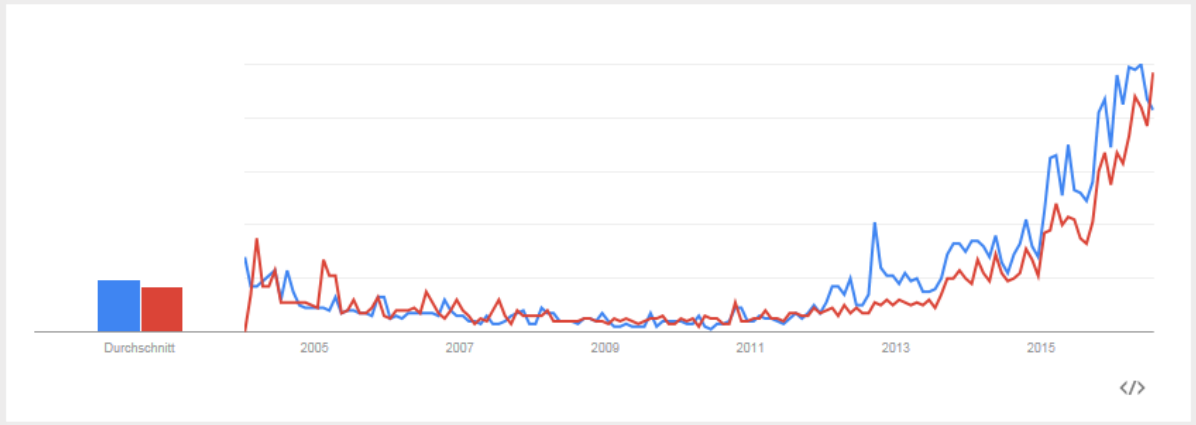


Autonomous systems

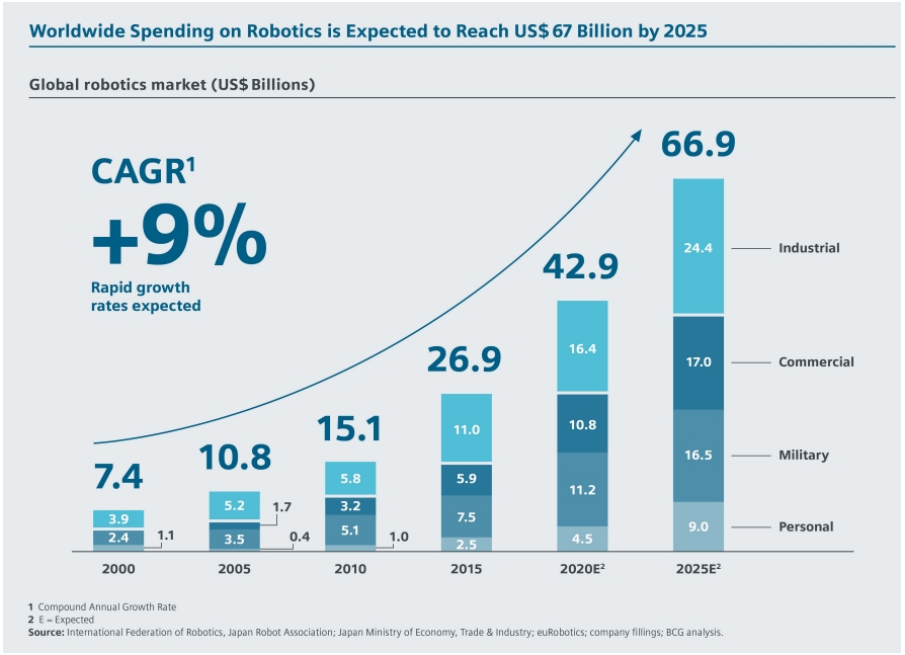
- From *auto* = *self* and *nomos* = *law* -> self-governing
- "an autonomous system has free will" [1]
- Common characteristics
  - **Knowledge:** The system knows facts about itself and its surroundings.
  - **Adaptation:** The system can adapt its own behavior dynamically to cope with changing surroundings.
  - **Self-awareness:** The system can examine and reason about its own state.
  - **Emergence:** Simple system elements construct complex entities.

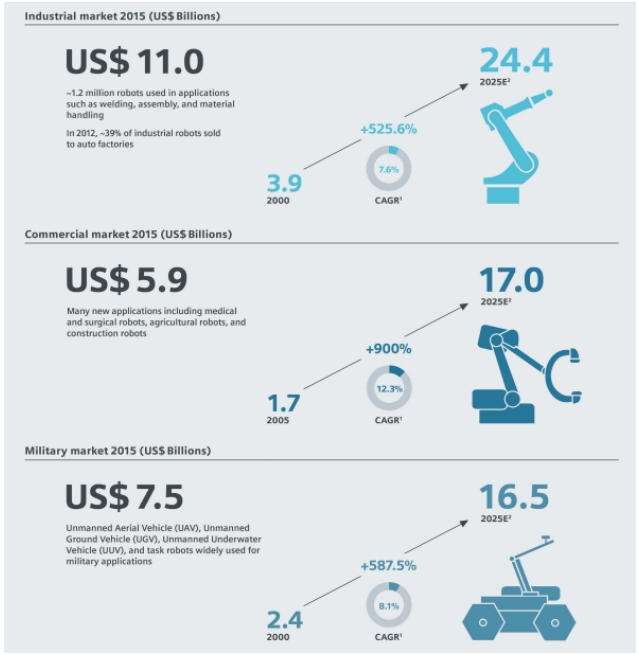
[1] Clough, B. T. (2002). Metrics, schmetrics! How the heck do you determine a UAV's autonomy anyway. Air Force Research Laboratory.

Trends


Durchschnitt
2005
2007
2009
2011
2013
2015
Autonomous cars
Autonomous driving

Numbers





Source: http://www.siemens.com/innovation/en/home/pictures-of-the-future/digitalization-and-software/autonomous-systems-infographic.html

Quotes

- “untapped short term market value of circa 7 billion per annum just for relatively low level autonomy products and services” [1]
- “potential economic impact of autonomous cars and trucks could be $200 billion to $1.9 trillion per year by 2025” [2]
- [they] estimate the total market for civilian robots at more than 10 billion euros in 2012 and continue that it ”should exceed 100 billion euros before 2020” [3]
- US DoD had planned to spend a $24 billion-plus total budget for unmanned systems in the 2007-2013 timeframe [4]

[1] Mallors, R. L. (2013). Autonomous systems: Opportunities and challenges for the UK. IET Seminar on UAVs in the Civilian Airspace.
[2] Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., & Marrs, A. (2013). Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey Global Institute San Francisco, CA, USA.
[3] Autefage, V., Chaumette, S., & Magoni, D. (2015). Comparison of time synchronization techniques in a distributed collaborative swarm system. European Conference on Networks and Communications (EuCNC) (pp. 455-459). IEEE.
[4] Clapper, J., Young, J., Cartwright, J., & Grimes, J. (2007). Unmanned systems roadmap 2007-2032. Office of the Secretary of Defense.

26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

TESTING AUTONOMOUS SYSTEMS

Testing autonomous systems

26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

- Unsolved issue
  - "testing autonomous systems is still an unsolved key area" [1]
  - "the major barrier that prevents the USAF from gaining more capability from autonomous systems is the lack of V&V methods and tools" [2]
  - "developing certifiable V&V methods for highly adaptive autonomous systems is one of the major challenges facing the entire field of control science, and one that may require the larger part of a decade or more to develop a fundamental understanding of the underlying theoretical principles and various ways that these could be applied" [2]
  - "there is a common misconception in the testing industry that all unmanned autonomous systems can be tested using methodologies developed to test manned systems" [3]

[1] Weiss, L. G. (2011). Autonomous robots in the fog of war. IEEE Spectrum, pp. 30-57.
[2] Dahm, W. J. (2010). Technology Horizons a Vision for Air Force Science & Technology During 2010-2030. Office of the US Air Force Chief Scientist.
[3] Thompson, M. (2008). Testing the Intelligence of Unmanned Autonomous Systems. ITEA Journal, pp. 380–387.

Testing autonomous systems is hard

26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

- **Complex environment**
- **Complex software**
- **Non-deterministic behaviour**
- **High expectations**

“THINGS TO DO”

“Things to do”

26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

1. **Use models**
2. **Be formal**
3. **Automate**
4. **Test early**
5. **Test continuously**
6. **Test virtually**
7. **Start by testing the correctness of the autonomy capability**
8. **Think ahead**

Thank you for your attention!

Airbus Group Innovations

Philipp Helle
Philipp.Helle@airbus.com

Wladimir Schamai
Wladimir.Schamai@airbus.com

Carsten Strobel
Carsten.Strobel@airbus.com