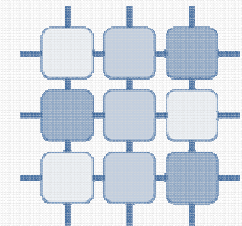


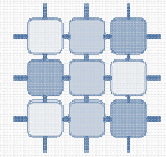
AGENT TECHNOLOGY for AEROSPACE APPLICATIONS



Dr. Michal Pěchouček,
head of the Agent Technology Center
Department of Cybernetics
Czech Technical University in Prague
pechoucek@fel.cvut.cz



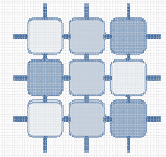
Agent Technology Center (ATG)



- ▶ ATG is a university research center performing fundamental and applied research in the field of agent-based computing, multi-agent systems and agent technologies.
- ▶ There are (Jan 2009) 22 researchers and 6 PhD students working in ATG. ATG researchers work on various cutting edge research projects, have unique set of skills and broad international experience.
- ▶ Research and technology development is funded in parts by the Czech Technical University in Prague, by the Czech Government, European Commission, European and US industry and US research and defense agencies.



ATG Mission Objective

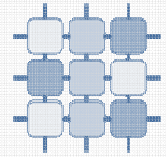


The main objective of ATG research is to contribute to:

- ▶ **fundamental research:** in agent-based computing and multi-agent systems
- ▶ **applied agent research:** in manufacturing, network security and defense
- ▶ **large scale prototype:** and demonstration systems development



ATG Core Competencies



▶ multi-agent modeling and simulations

- » scalable simulation of communities of interacting actors, e.g. *air traffic, adversarial scenarios, design & manufacturing processes, car electronics*
- » AGLOBE/XSIMULATION, hardware deployment in collective robotics

▶ multi-agent planning and coordination

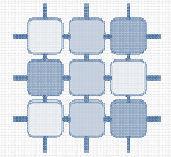
- » advanced methods of planning and resource allocation and coordination
- » optimization of coordinated behavior in distributed systems,
- » plan merging, repair and coordination, social commitments enabled plans

▶ multi-agent data analysis

- » distributed datamining and multi-agent learning
- » targeted towards heterogeneity and private knowledge confidentiality
- » applications in *computer security, maritime domain awareness*

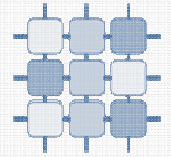


Agent Technology for Aerospace Applications



- ▶ **Planning tools:** for solving complex trajectory planning, mission planning and resource (such as air space) allocation
- ▶ **Simulation tools:** for simulating nontrivial, massive air traffic scenarios, performing computational experiments with air safety regulations
- ▶ **Control tools:** for on-line control of aerial assets, such as UAS, performing autonomous *free-flight* containing *sense-and-avoid* capability

AGENTFLY Project: Task specification



US AIRFORCE (OSD/AFOSR/EOARD/AFRL) funded in 2006-2008:

▶ Multi-agent technology **demonstrator** of a *flexible, free-flight, collision-free air-traffic operation*

▶ the **research task** was to investigate *theoretically* and *empirically*:

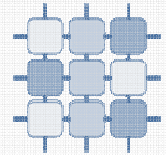
- » efficiency of free-flight concept
- » robustness of free-flight concept
- » scalability of free-flight concept

▶ **application orientation**:

- » fly higher number of aircrafts in restricted airspace
- » decrease cognitive load and the need for direct human involvement
- » allow combination of cooperative and non-cooperative deconfliction

www.agentfly.org

AGENTFLY Project: Deployed Capabilities

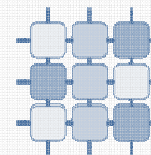


- ▶ AGENTFLY system provides:
 - » multi-agent model for **flight simulation** of fixed-wing aircraft
 - in *AGLOBE* multi-agent development environment
 - » efficient 4D trajectory **planning algorithm**
 - based on original *Accelerated A** algorithm
 - » multi-layer **collision avoidance** architecture with 4 advanced methods
 - » first version of **collective flight** coordination architecture
 - » GPS model of the environment, weather model
 - » set of coordinated **information collection** planning algorithms
 - » external data collection and fusion (Landsat images, airports, no-fly zones),
 - » 2D/3D advanced visualization and user interface

- ▶ In Dec 2008 patent application submitted

Pechoucek, M. - Šišlák, D.: Agent-Based Approach to Free-Flight Planning, Control, and Simulation, *IEEE Intelligent Systems* vol. 24 (1), 2009 . ISSN: 1541-1672

AGENTFLY: Free-flight



speed: normal
current time: 240

Pointer: X: -69,545 Y: 36,353
fps: 9



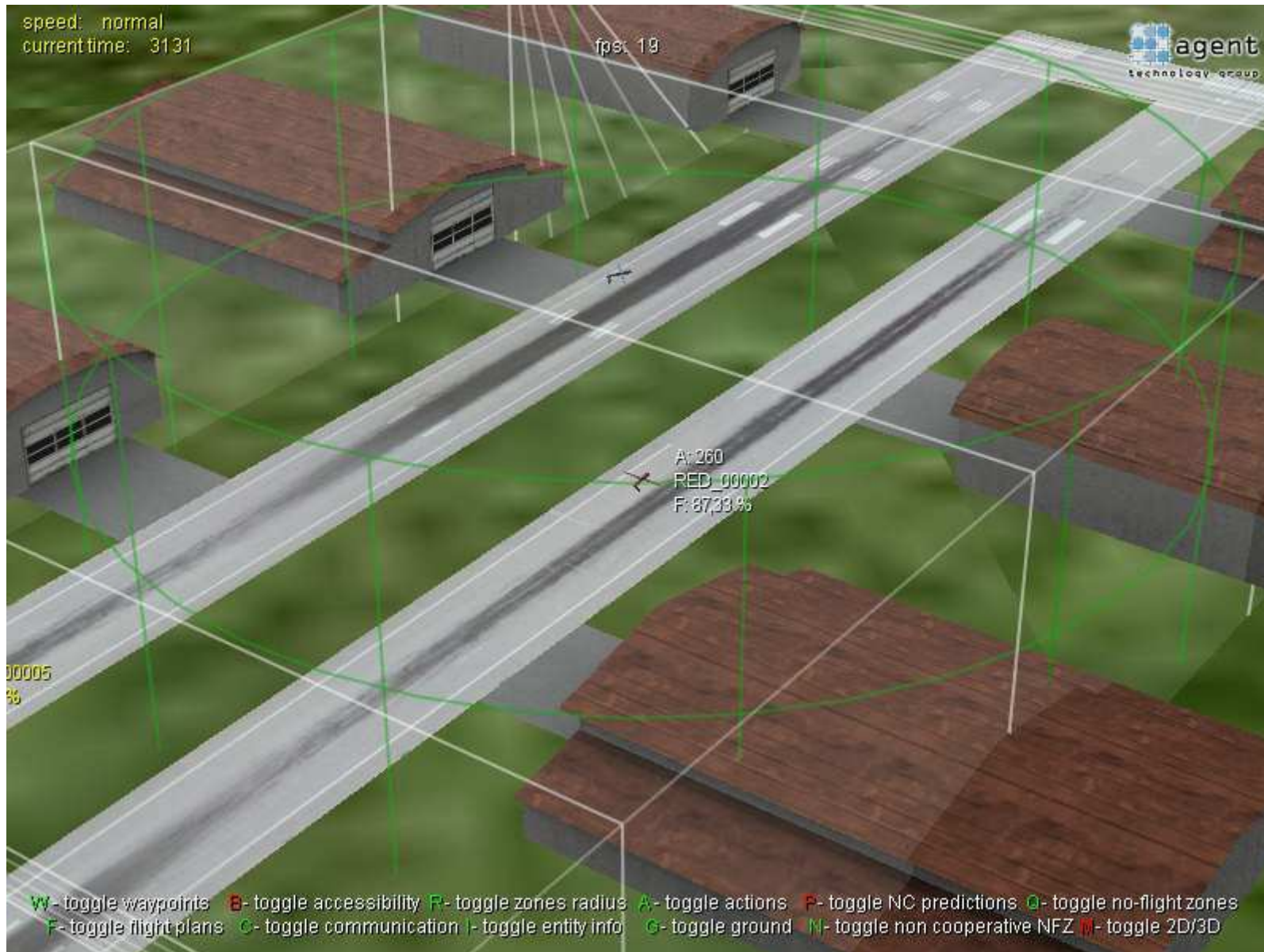
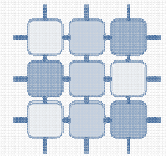
Plane00001

Plane00002

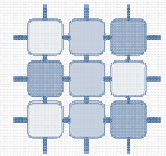
W- toggle waypoints B- toggle accessibility R- toggle zones radius A- toggle actions P- toggle NC predictions M- toggle 2D/3D
F- toggle flight plans C- toggle communication I- toggle entity info G- toggle ground N- toggle non cooperative NFZ

The image shows a dark green grid-based simulation environment. At the top left, there is a status bar with text: 'speed: normal' and 'current time: 240'. At the top center, there is a pointer status: 'Pointer: X: -69,545 Y: 36,353' and 'fps: 9'. At the top right, there is a logo for 'agent technology group'. In the lower-left and lower-right areas of the grid, there are two small aircraft icons labeled 'Plane00001' and 'Plane00002' respectively. At the bottom of the screen, there is a legend for various toggle keys: 'W- toggle waypoints', 'B- toggle accessibility', 'R- toggle zones radius', 'A- toggle actions', 'P- toggle NC predictions', 'M- toggle 2D/3D', 'F- toggle flight plans', 'C- toggle communication', 'I- toggle entity info', 'G- toggle ground', and 'N- toggle non cooperative NFZ'.

AGENTFLY: Planning



AGENTFLY: Collision avoidance



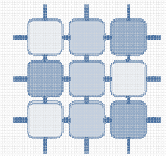
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current time: 3424

Pointer: X: -125,810 Y: 17,830
fps: 1

 agent
technology group

W - toggle waypoints B - toggle accessibility R - toggle zones radius A - toggle actions P - toggle NC predictions M - toggle 2D/3D
F - toggle flight plans C - toggle communication I - toggle entity info G - toggle ground N - toggle non cooperative NFZ

AGENTFLY: Collision avoidance



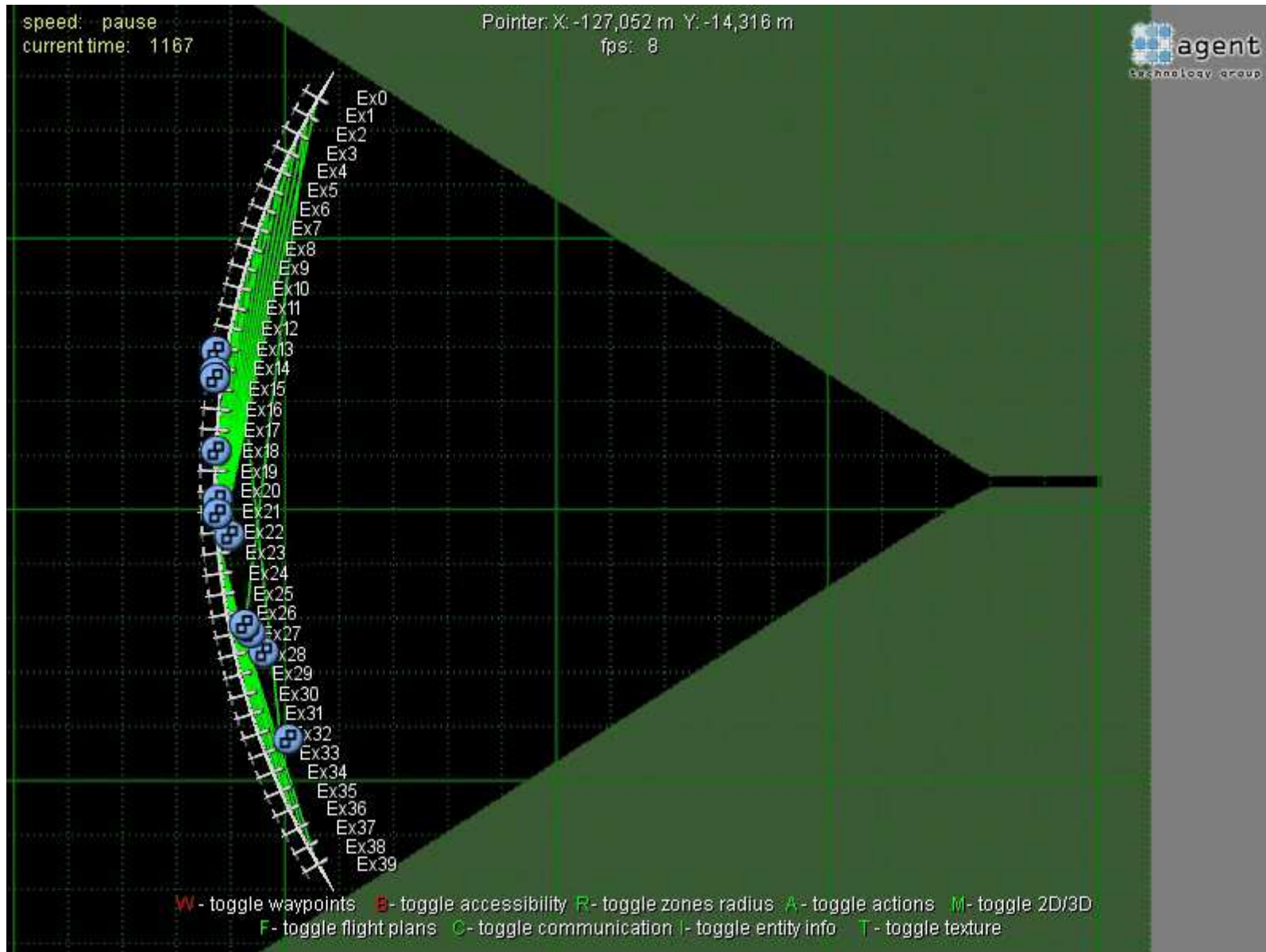
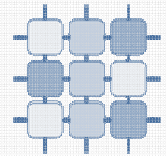
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current time: 356

Pointer: X: -110,620 Y: 26,122
fps: 1

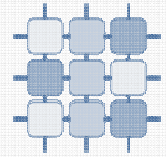
agent
technology group

W- toggle waypoints B- toggle accessibility R- toggle zones radius A- toggle actions P- toggle NC predictions M- toggle 2D/3D
F- toggle flight plans C- toggle communication I- toggle entity info G- toggle ground N- toggle non cooperative NFZ

AGENTFLY: Landing scenario



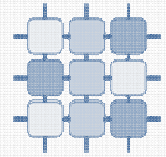
AGENTFLY Project: Technology Take-Up



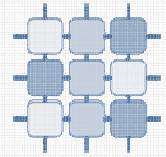
- ▶ BAE Systems: Testing of *Probability collective* collision avoidance
- ▶ IHMC US: Evaluating PIM (Process Integrated Mechanism) in robotics
- ▶ US Army: Tactical Planning of Information Collection Missions



ATG Tech: Mixed Information Collection Planning



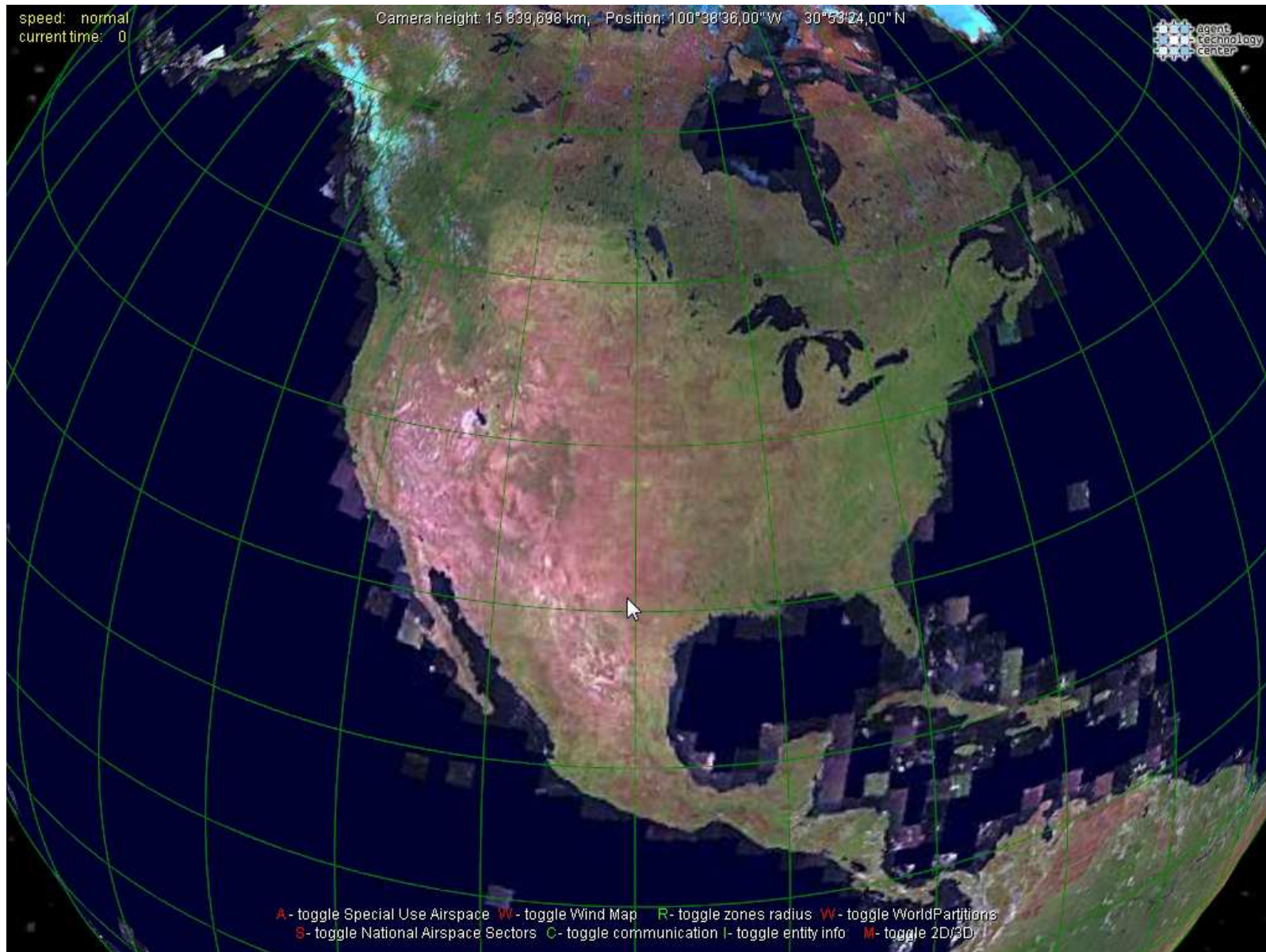
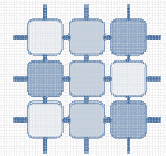
AGENTFLY Project: Technology Take-Up



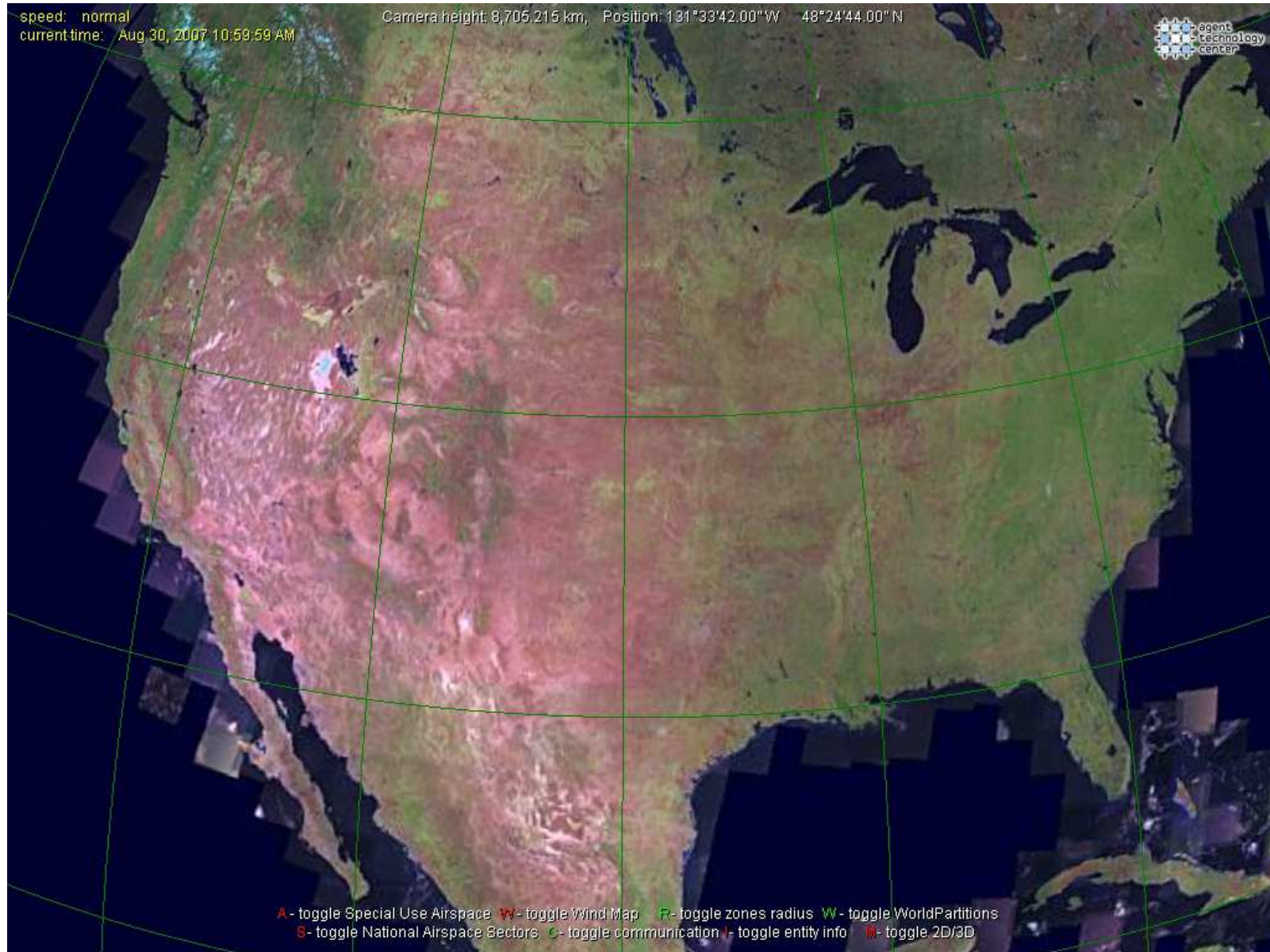
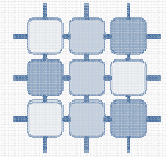
- ▶ BAE Systems: Testing of *Probability collective* collision avoidance
- ▶ IHMC US: Evaluating PIM (Process Integrated Mechanism) in robotics
- ▶ US Army: Tactical Planning of Information Collection Missions
- ▶ FAA: Use of AGENTFLY for simulation of air traffic in NAS



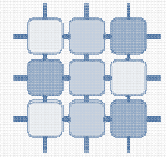
ATG Technology: Scalable Multi-agent Simulation



ATG Technology: Scalable Multi-agent Simulation



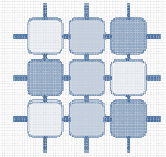
AGENTFLY Project: Technology Take-Up



- ▶ BAE Systems: Testing of *Probability collective* collision avoidance
- ▶ IHMC US: Evaluating PIM (Process Integrated Mechanism) in robotics
- ▶ US Army: Tactical Planning of Information Collection Missions
- ▶ FAA: Use of AGENTFLY for simulation of air traffic in NAS
- ▶ SAAB/Linkoping University: Deployment of AGENTFLY on Skeldar VTOL
- ▶ US Navy/CMU: Deployment of AGENTFLY on PROCERUS UAVs



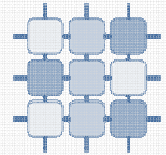
Other promising applications of agent technology



- ▶ Modeling and coping with adversarial reasoning in distributed environment:
 - » **Security provisioning in Maritime domain:** scheduling the ship patrols by game-theoretic methods and multi-agent modeling
 - Funded by the US NAVY, ONR
 - » **Network security:** methods of intrusion detection and attack modeling for high-speed computer networks
 - Funded by the US Army
 - Spin-off company: Cognitive Security

cognitivesecurity

ATG contracts with DoD and other US gov. agencies



Air Force

Agent-based Computing in Distributed Adversarial Planning, FA8655-07-1-3083 (2007-2009)
Autonomous Agents for UAV Air-Traffic Control, FA8655-04-1-3044-P00001 (2005-2007)
Advanced Agent Methods in Adversarial Environment, FA8655-04-1-3044 (2004-2005)
Meta-reasoning and Monitoring in the Multi-Agent Systems FA8655-02-M4056 (2002-2003)
Agents Inaccessibility in Multi-agent Systems FA-8655-02-M-4057 (2002-2004)
Acquaintance Models in OOTW Coalition Formation F61775-00-WE043 (2002-03)
Multi-Agent Systems in Communication, F61775-99-WE099 (1999 - 2000)



ARMY

Unmanned System Command & Control for Operations in Urban Terrain W15P7T-05-R-P209 (2009)
Intelligent Software Agent Control of Combined UAV Operations for Tactical Missions (2008-2009)
Agent-based Control for Connectivity: Maintenance of Tactical MANETS W90C2K1317-CE-01 (2008-09)
Distributed Planning and Coordination of Team-oriented Activities in a Dynamic Environment, W911NF-08-1-0041 and N62558-06-P-0353, subcontract provided to University of Edinburgh (2006-08)
Cooperative Adaptive Mechanism for Network Protection N62558-07-C-0001, (2007)
Modeling Individual, Collaborative and Adversarial Reflection N62558-05-C-0028 (05-07)
Reflective/Cognitive Agent in Distributed Decision Making N62558-04-C-6001 (2004-2005)
Modeling in Multi-agent Systems: A Technology Primer, N62558-03-0819, (2004)

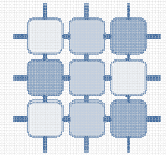


Navy

Adversarial Modeling and Reasoning in the Maritime Domain N000140910537 (2009-11)
Meta-reasoning and Adjustable Autonomy in Comput. MAS N00014-06-1-0232 (05-08)
Robot coordination using PIM, subcontract awarded by Florida IHMC, US N00014-06-1-07756 (07)
Meta-reasoning for Modeling and Simulation in Multi-Agent Systems N00014-03-1-0292 (2003-2005)
Consultation and architecture design for a shipboard chilling system - with Rockwell Automation



Industrial Collaboration



- ▶ **GOOGLE (CH):** Adjustable Privacy in Social Networks (Research Award in 2009)
- ▶ **FAA (US):** Deployment of AGENTFLY in civilian air traffic domain
- ▶ **NASA (US):** Collaboration by means of a subcontract provided by IHMC
 - » HYRES project: development of agent based root-cause detection, in hydrogen production facility, (2003)
 - » Robot coordination using PIM, subcontract awarded by IHMC (2007-2008)
 - » Harry Swenson, NASA PM in ATG 2009-2010
- ▶ **BAE Systems (UK):** Deployment of the AGENTFLY multi-agent system as a test-bed for probabilistic collision avoidance strategies (2007-2008)
- ▶ **ROCKWELL AUTOMATION RESEARCH CENTER** in Prague (CZ): design of agent-based reconfiguration shipboard automation for chilling system (2002)
- ▶ **DENSO Automotive, GmbH:** Agent based diagnostics in vehicle electronics directed towards facilitating graceful degradation (2005-2007)
- ▶ **CADENCE Design Systems, GmbH (D):** consultation services in design and development of an agent-based system for IC design management