Innovation in Systems and Control: Identifying and Exploiting New Opportunities

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Who Is Honeywell?

Systems and Control Core to All Businesses

Aerospace

$15.7 Billion

Automation and Control Solutions

$13.5 Billion

Performance Materials and Technologies

$9.9 Billion

2013 Sales, $B
## Great Positions in Good Industries

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<th>Aviation &amp; Defense</th>
<th>Automotive &amp; Transportation</th>
<th>Buildings, Construction &amp; Maintenance</th>
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<tr>
<td>Chemicals, Specialty Materials &amp; Fertilizers</td>
<td>Consumer &amp; Home</td>
<td>Efficiency, Energy &amp; Utilities</td>
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<td>Fire Protection &amp; First Responder</td>
<td>Manufacturing</td>
<td>Natural Gas, Refining, Petrochemicals &amp; Biofuels</td>
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<td>Safety &amp; Security</td>
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Outline

From research and development to products and solutions—systems perspective

A few Honeywell innovations from R&D in Europe/NL

*The Impact of Control Technology, 2nd ed.*—a resource for “success stories” and “research challenges” in automation and control
From Ideas to Successful Products

Innovation Funnel – from R&D explorations (many small-scale projects) to launched products (a few large-scale projects)

Open innovation – technology from external sources, e.g., universities
Technology Readiness Levels

Well-established and widely used metric for assessing maturity of technology development. Different versions developed for different organizations (NASA’s shown below) and technologies (e.g., software, manufacturing).

- TRL 1 Basic principles observed and reported
- TRL 2 Technology concept and/or application formulated
- TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept formulated
- TRL 4 Component/subsystem validation in laboratory environment
- TRL 5 System/subsystem/component validation in relevant environment
- TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space)
- TRL 7 System prototyping demonstration in an operational environment (ground or space)
- TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space)
- TRL 9 Actual system "mission proven" through successful mission operations (ground or space)

The “valley of death” in the middle of the scale . . . organizations that can bridge the research/practice gap are crucial
Control systems in context

Control algorithm design cannot be isolated from its deployment environment—the importance of systems engineering and integration
Advanced Control – Industry-specific Considerations

• Value chain: who does the control design, software development, integration?
• How many identical copies of a controller will be deployed (one to millions)?
• How easy or difficult is it to “adjust” a fielded control algorithm?
• What variety of conditions will be encountered in practice?
• Is the application safety critical?
• What regulatory and certification requirements must be addressed?
• What is the expected lifetime of the application?
Simplified value chains for control algorithms

Aerospace

Algorithm developer

Software implementer

Control system supplier

OEM

Airline or leasing company

University research group or in-house R&D

Controls company or third-party application house

“Controls company” (Collins, Honeywell, Thales, …)

Aircraft manufacturer (Airbus, Boeing, Bombardier, Embraer, …)

EPC

Process industry

Algorithm developer

Software implementer

Control system supplier

EPC

Process plant owner

University research group or in-house R&D

Controls company or third-party application house

“Controls company” (ABB, Emerson, Honeywell, Invensys, Siemens, Yokogawa, …)

(AMEC, Bechtel, Fluor, FosterWheeler, Samsung Eng., WorleyParsons, …)

(ExxonMobil, Shell, Reliance India, Sinopec, Weyerhauser, …)

Many complexities not considered. Value chains for other control technology developments, such as control design tools, will be different. Significant variations within these broad industry sectors exist.

The ultimate beneficiary of a technology is typically not who must be convinced of its value!
Differentiating Control Applications—Examples

Engine Control Development Process

- Engine and Desired Performance
- Steady-State Engine Calibration
- Control Functional Development
  - Functional Testing (simulation, testbench, vehicle)
  - Software Development (specification, testbench, vehicle)
  - Integration (testing and debugging)
  - Calibration (simulation, testbench, vehicle)
- Certification and Release

Papermaking Control Development Process

- Control Functional Development
  - Software Coding
  - Software and Control Testing
  - Control Product Release
  - On-Site Commissioning (model process, configure and tune control)
  - Post-Commissioning Maintenance
- Paper Machine and Desired Performance

G. Stewart and T. Samad, in *The Impact of Control Technology*, ieeecss.org/main/loCT-report

**A crucial question: When can we have access to the system, or its model? The answer depends on the industry sector.**
The “So what?” of advanced control

• Benefits typically a combination of
  - accelerated development time—design, development, calibration, testing, . . .
  - enhanced insight or simplified development process
  - system performance in normal operating conditions
  - robust performance to product variations and in off-nominal conditions
  - reliability and fault tolerance
  - reduced cost of capital and operation

• And these must all be considered in context
  - . . . relative to current solutions and alternatives
  - . . . given the current business and technical environment
## The Value of Advanced Controls for Honeywell

### Honeywell

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<th>Industry</th>
<th>Example Applications</th>
<th>Realized Benefits</th>
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| Oil Refining Petrochemicals Oil and Gas | Refinery, Ethylene Plant, Aromatics, Xylene, Gas Processing, LNG/LPG | • 2-15% higher production  
• Refinery: ~$1/Barrel for advanced control  
• 5-20% less energy/unit product |
| Pulp & Paper | Cross/Machine Directional Control | • Up to 50% higher performance  
• 50-80% lower calibration time |
| Building Control | HVAC adaptive control | • 7-33% energy cost savings  
• Low setup costs |
| Commercial Aircraft | B787, C919  
EPIC, APEX | • Stabilization of unstable aircraft  
• Level 1 handling qualities |
| Aero Engines | AS907-1  
HTF 7500E  
HPW3000 | • 99.7% fault coverage  
• Optimized engine start  
• Improved engine life with power assurance |
| Space | Orion Multi-Purpose Crew Vehicle | • reduced propellant requirements by 20%  
• optimal steering of Control Moment Gyro |
| Military & Unmanned Aircraft | Reusable Launch Vehicle, T-Hawk | • Stabilization, Vehicle Utility & Operability  
• 4X less development time  
• Missions completed after component failures |

- Problem dimensions up to 1000s of measurement points, 100s of actuators
- Dynamics from milliseconds to minutes

### 30+ years of advanced control leadership and successful products
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Advanced Domestic Combi Boiler Controls

• New demands on combi boilers in EU
  - reduced complexity and cost reduction
  - compliance with tightening regulations
  - variable gas quality/composition

• Several innovative features in latest boiler control systems:
  - gas valve with Integrated combustion safety control, fan drive and gas adaptive control
  - ionization combustion feedback is a function of lambda and firing rate
  - trimming system allows for fast operation and adaptation to gas quality at convenience
  - concept is suitable for other sensing technologies (CO/ O2)

• Benefits: adjustment-free installation, energy efficiency, continuous adaptation to gas quality, application across natural gas and LPG ranges

• Honeywell center of excellence in electronic boiler controls and gas valves in Emmen

For more information: http://ecc.emea.honeywell.com/
Ultrasonic Flow Meter

• High-precision, highly reliable measurement systems needed for gas transmission networks worldwide

• Key customer requirements:
  - lower capital costs
  - lower operational costs
  - high reliability

• New GT400 flow meter features:
  - ultrasonic measurement of velocity profile of gas flow
  - “live” precision adjustment
  - superior noise immunity from flow regulation disturbances
  - condition-based monitoring for real-time detection of flow nonlinearities
  - compliance with stringent metrology standards; global agency approvals

• Honeywell Field Solutions engineering leadership in Delft

For more information: http://www.rmg.com/en.html
Universal Safety I/O for Process Automation

- Sensors and actuators connected through I/O modules to process and safety control systems in plants
  - typically separate modules for inputs and outputs, analog and digital signals
- Universal I/O innovation at Honeywell allows software configurability of each channel
  - field device connections to any channel
  - accuracy and functional safety certifications maintained
- $10Ms - $100Ms savings (large projects):
  - simple, cost-effective installation and maintenance
  - lower installation and operational costs with flexible I/O types and configuration
  - up to $1000 savings/channel
- **Honeywell safety systems R&D in ‘s-Hertogenbosch**

Applications to other safety-critical sectors as well as process plants

For more information:  [http://www.honeywellprocess.com](http://www.honeywellprocess.com) (“safety systems”)
Model-Based Automotive Powertrain Control

• Challenges facing the transportation industry:
  - > $1B spent on control design & calibration
  - lines of code increasing 10X / 8 years
  - development cost for software will exceed that for hardware before 2020
  - controls being developed using non-systematic approaches

• Model-based control and systems engineering—OnRamp by Honeywell
  - invention and innovation in modeling, control design, and deployment

• Benefits:
  - clean-sheet development time for transient control: months → weeks
  - > 1 FTE annual savings per license
  - > 2% fuel efficiency improvement (est.)
  - > 50% reduction in actuator activity

• Collaboration under way with TU/e—first university to receive OnRamp

For more information:  http://www.honeywellonramp.com
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The Impact of Control Technology

- Second edition of *The Impact of Control Technology* now available (T. Samad & A. Annaswamy, eds.)
  - sponsored by IEEE CSS and AACC
- Report content is 68 two-page full-color flyers
  - 30 “Success Stories in Control”
  - 38 “Challenges for Control Research”
- Available freely and without copyright restrictions (except where otherwise indicated)
  - [ieecss.org/general/IoCT2-report](http://ieecss.org/general/IoCT2-report)

*Highlights of a vibrant discipline and community!*
H-infinity Control for European Telecommunication Satellites

Telecommunication Satellite Control System Design: Challenges and Needs

Constituent telecommunication satellite platforms typically consist of a control body and large deployable solar arrays together with four damping flexible solar arrays that are rotating with respect to the Earthpointing control body at a rate of one rotation per day. During such inclination correction maneuvers, the satellite is subjected to heat-Induced disturbances, in particular those that require some few tens of nanometers control authority to limit the attitude deviations below 0.1 deg. Because of the low damping (typically 10%) and slightly frequency modes with high resonant peaks of the large rotating solar arrays (see figure below), a stiff filtering controller is required. Using classical control design techniques, the design problem is solved.

Dynamics and Control for Deep-Sea Marine Risers

A marine riser is a long, slender, flexible riser extending from the subsea wellhead or manifold to the ocean surface. It is subjected to a fluid's dynamic pressure, environmental loads, and fluid motion, and must maintain its integrity under these conditions.

Advanced Control of Pharmaceutical Crystallization

Pharmaceutical manufacturing processes use crystallization to generate materials for producing high purity, efficiency, and reliability. Process optimization, monitoring, automation, and control systems are now widely used for the design and development of pharmaceutical crystallizers.

Success Stories For Control

Control in Stroke Rehabilitation

Stroke is the fourth leading cause of disability in developed countries, behind heart disease and diabetes mellitus. Following a stroke, patients often experience significant difficulties in performing everyday tasks such as feeding, dressing, and bathing. The development of rehabilitation systems that can help patients recover these skills is crucial. An example of such a system is the Rehabilitation System for Stroke (RtS), which has been developed at the University of Michigan. RtS uses computerized training modules to help patients with neuromotor rehabilitation.

Autopilot for Small Unmanned Aerial Vehicles

Small unmanned aerial vehicles (UAVs) have numerous applications in various sectors. These include monitoring, mapping, and measuring of land, water, and air; environmental monitoring, and surveying. The autopilot system for these UAVs must be able to navigate in various environments with minimal human intervention.

Success Stories For Control

Road Grade Estimation for Advanced Driver Assistance Systems

Modern vehicles are equipped with many assistance control systems that aid the driver in operating the vehicle safely and economically. Knowledge of the current and future road grades can be used by these systems to improve efficiency and reduce fuel consumption. The development of road grade estimation systems is crucial for the design of autonomous vehicles.

Vehicle Fleets as Sensor Networks

As long as vehicles are on the road, they can provide valuable information about traffic conditions, traffic congestion, and other factors that affect driving. By using the data collected by sensor networks, it is possible to estimate road grade information. This information can be used to improve traffic flow and reduce congestion.
**Challenges for Control Research**

**Preview Control of Wind Turbines**

Wind and solar are the primary sources for wind turbines but also they are not distributed to the different types. Thus, knowledge of the wind is vital to control the operation of wind turbines and reduce the risk of failure. The control of a wind turbine is a complex task that requires the integration of various technologies.

**Control Challenges**

Control strategies need to be robust to changing operational conditions. To achieve this, a range of advanced control techniques are employed.

**Addressing Automotive Industry Needs with Model Predictive Control**

The automotive industry faces significant challenges due to increased demand for fuel economy and reduced emissions. Advanced control technologies are playing a crucial role in addressing these challenges. Model Predictive Control (MPC) is one such technology that is being increasingly used in the automotive industry.

**Three Examples of Automotive Challenges for Advanced Control**

- **Cornering and Stability Control**
- **Advanced Control of Active Suspension Systems**
- **Advanced Control of Active Brake Systems**

**Management of Complex Water Networks**

Water security is one of the most pressing issues facing the world today. Advanced control technologies are being used to manage complex water networks effectively. These technologies help in optimizing the use of water resources and reducing water losses.

**Toward Verifiably Correct Control Implementations**

Bugs may be introduced into control applications at all levels, starting from the high-level mathematical control laws to the actual machine code, complete with device drivers and multitasking. An important aspect of ensuring the correctness of control implementations is to verify that the system is free from bugs.

**Safer, More Powerful Compilations**

Compilers are software that convert high-level programming languages into machine code. A bug in a compiler can lead to severe consequences, as it can result in the generation of incorrect machine code. Therefore, it is essential to ensure that compilers are free from bugs.
Concluding Remarks

• Demonstrated value from systems and control across the industry sector spectrum . . .
• . . . and no shortage of new challenges for societal and industry impact
• Control in the technology context: sensors, actuators, communications, computation, human-machine interaction, . . .
• Systems in the business context: requirements, value chain, maturity levels, roadmaps, regulators, costs, . . .
• New and renewed imperatives for research and application:
  - distributed and coordinated control
  - verification and validation of complex closed-loop systems
  - gray-box modeling and identification
  - human-in-the-loop systems and user-centered design
  - the Cloud as a platform for applications
  - Big Data . . . and small data too

TU/e: a university that understands the complexities of high-tech systems engineering and integration!
Congratulations to the High Tech Systems Center and I look forward to more accomplishments from TU/e!