

Autonomy and Intelligent Technologies for Advanced Inspection Systems

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ABSTRACT

This paper features a set of advanced technologies for autonomy and intelligence in advanced inspection systems of facility operations. These technologies offer a significant contribution to set a path to establish a system and an operating environment with autonomy and intelligence for inspection, monitoring and safety via gas and ambient sensors, video mining and speech recognition commands on unmanned ground vehicles and other platforms to support operational activities in the Cryogenics Test bed and other facilities and vehicles. These advanced technologies are in current development and progress and their functions and operations require guidance and formulation in conjunction with the development team(s) toward the system architecture.

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INTRODUCTION

A sample of advanced and innovative technologies under research and development are being investigated to facilitate operations and benefit autonomy and intelligence of advanced inspection systems. These innovative technologies show an established history with a sustainable and fundamental research base, supported industrial development, and extensive presence and growth in industrial operations and in new emergent markets. As importantly, these technologies exhibit characteristics of high-impact concepts of innovation and capacity for far-reaching potential in the near future. Innovation is a highly desired feature of valuable new technologies, in the sense of providing effective solutions and success for meeting requirements while adding new value, and new operational techniques and methods, and in our case, improving autonomy and intelligence. These qualities are part of a continuous process in successful enterprises, increasing progress and accelerating growth and development. It is compelling at present times to introduce in business practices innovative technologies when we are at the threshold where significant technical innovations are changing our life style with mobile devices, intelligent sensors, smart vehicles, miniaturized satellites, advanced automation in manufacturing and facility operations, as well as, in homes, cars, offices and all kind of places [1, 2, 3, 4]. Innovation is fundamentally changing everything and

massively revolutionizing our daily actions and the work inside and outside of our organizations, and embracing these innovations is only a matter of time and opportunity.

Advanced technologies are of foremost importance to NASA for future space and science missions, and NASA is developing different programs to enable automation and intelligence. The Game Changing Development (GCD) program investigates novel ideas and approaches and seeks to identify and rapidly mature innovative/high impact capabilities and technologies for infusion in a broad array of future NASA missions [5]. This program manages 23 projects, including Autonomous Systems (AS) to develop and demonstrate automation technologies to operate habitats through its Habitat Automation (HA) element and cryogenic loading through its Autonomous Cryogenic Loading Operations (ACLO) element, to enable cost-efficient autonomous ground operations and to develop smart sensing approach to cryogenics monitoring [6]. The Advanced Exploration Systems (AES), a program of NASA's Human Exploration and Operations (HEO) Mission Directorate, pioneers new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. A major goal of this program is to "leverage innovative new approaches to affordably develop needed capabilities for sustained human exploration," [7]. This program manages about 20 projects, including the Integrated Ground

Operations Demonstration Units (IGODU) to evaluate innovative intelligent tools and techniques and advance autonomous control technologies for future applications, demonstrating cost-efficient control of hazardous cryogenic propellant transfer and storage for launch operations. These complex operations are researched with innovative tools, appropriate sensing technologies and advanced health-management capabilities to avoid significant past operational cryogenic propellant losses. This project is demonstrating new techniques and technologies in a controlled environment at the Cryogenic Test Bed laboratory shown in [figure 1](#) and located at Kennedy Space Center (KSC) [8].

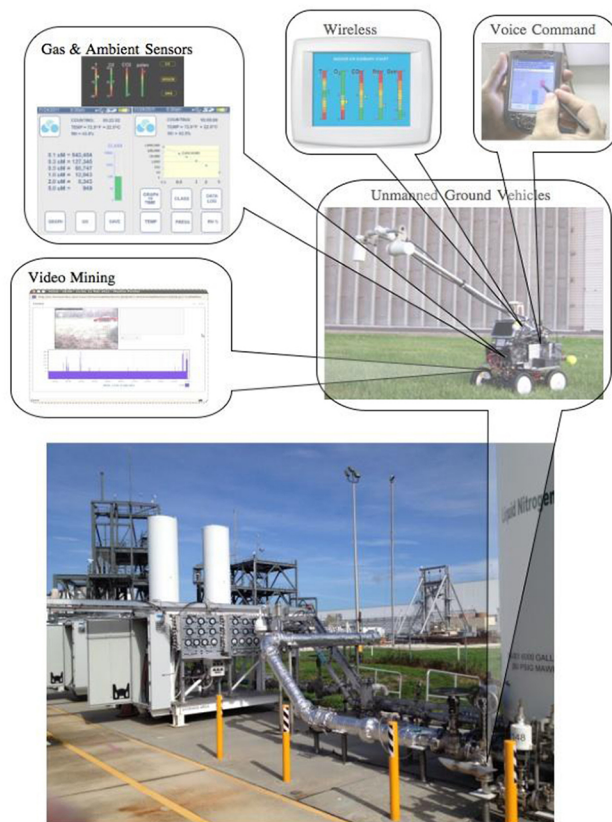


Figure 1. Advanced technologies for in situ sensing.

This paper addresses the following topics on advanced technologies:

- Advanced technology and its foundation on the Silicon Valley,
- Intelligent sensors: present innovative intelligent thermostats, intelligent gas sensors development, and intelligent gas sensors for advanced inspection systems,
- Voice command and control, current factors and present natural speech recognition with pronunciation and noise developments,
- Advanced video - data mining within a Unix framework for security and safety qualities, and an

- Unmanned ground vehicle as a useful and practical platform for autonomy and intelligent sensors.

ADVANCED TECHNOLOGY

The broad search of which innovative technologies should we embrace is a challenge in itself. Defining which new technologies should be implemented, and which innovations will prevail in each organization is not a clear path; it implies a complex decision process guided with sufficient acquired relevant information to assess emergent technologies and implement them. In this paper, this search is guided through gathering information from successful sources and a process of selective decisions on innovative technologies that can be applied at this time in facility operations. As important as to introduce innovative technologies, it is to build and enhance a business culture that promotes implementations of successful innovations [4].

Ames Research Center is located in the Silicon Valley, and its geographical location provides great opportunities for interaction with advanced technology companies and leaders in sciences and technology. Very large and successful companies and very relevant emergent companies are presently located in the Silicon Valley, demonstrating a solid statement of innovation in technology. Successful established companies and emerging companies in this valley convey a total market value of about 2 trillion dollars and total annual sales of about 700 billion dollars, considering companies with over ten billion dollars of 2012 annual sales. The market value of these companies represents a significant statement by itself, about 11% of the total market capitalization of listed companies in the USA. Companies with top market value Well-known traditional large companies show top values in market values and annual sales the current birth of expected largest companies with very large market value over annual sales due to their large expected future growth. Comparison of these companies provides a sense of the new areas of development that are emerging and the future of technology.



Figure 2. Silicon Valley Companies [9].

A view of the top 150 companies in the Silicon Valley shows different trends among large traditional companies and new emergent companies in their main areas of activities, a trend toward successful technologies [2]. Companies with over \$10 billion of annual sales in 2012 include Apple Inc., Hewlett-Packard, Intel, Google, Cisco Systems, Oracle, eBay, and Synnex. These companies focus their operations mainly on semiconductors, hardware and software, Internet equipment and services, and their technologies represent traditional technologies of the Silicon Valley. Emergent companies with very high economical expectations, as indicated by their large market value over annual sales, infer a new trend in operations and technologies. Companies with over 10 times market value over annual sales in 2012 include Workday, Pharmacyclics, Splunk, LinkedIn, Medivation, NetSuite, Onyx Pharmaceuticals, Theravance, Palo Alto Networks, Facebook, Solarcity, Yelp, and Tesla Motors. These companies focus their operations in biopharmaceuticals, cloud applications, big-data, social networking, green energy, network security and Internet applications. These companies also embrace new technologies in their endeavor for success and search for new applications and markets. The analysis of the new technologies adopted by these emerging companies provides a valuable source of information and base for decision-making on new technologies.

Similar to the development and widespread use of graphical user interfaces (GUIs), there is a strong surge and innovation on nontraditional interfaces. This development is guided by the fundamental wisdom needed to do the human factors work efficiently with advanced and superior interfaces based on human strength and limitations. Haptic or touch screen interfaces (cell phones, game consoles), gesture interfaces with hand and face movements, locomotion interfaces (high-end simulators, home gaming boxes), auditory interfaces for simple coded messages, speech user interfaces (cell phones), interactive voice response interfaces (commercial phone services), olfactory interfaces (alarm systems), taste interfaces (innovative food simulators), and combinations with multimode interfaces [10]. Recently, Intel announced a new interface to control computers and other devices with gaze, gesture, voice and touch [11].

The search of advanced technologies is very broad and several innovative technologies are under investigation to improve autonomy and intelligence in complex operations. The areas of advanced interfaces for communications, control and command, advanced sensor for inspection and monitoring, augmented reality to enhance and revolutionize big data, and 3D visualization to accurately convey information on complex processes are under investigation. In the following sections, four technologies are described as a single set as a representation of advanced technologies that can be implemented at present times in the path to develop an advanced system with a culture for advanced autonomy and intelligence. In this set,

- **Advanced Gas and Ambient Sensors (AGAS)** shows advanced technology developed in the semiconductor industry and now been applied into new markets and operations,
- **Voice Command and Control (VC&C)** as a safe and efficient interface in complex environmental sites,
- **Advanced Video Monitoring and Data Mining (AVM-DM)** for monitoring and inspection in a closed Unix environment, and an
- **Unmanned Ground Vehicle (UGV)** as a base to integrate and show technologies supporting mobility and autonomy.

INTELLIGENT SENSORS

Silicon Valley continues to be the leading hub for high-tech innovation and development, and accounts for one-third of all of the venture capital investment in the United States [12]. The technologies developed in this valley have produced advanced and accurate technologies derived by the needs of efficiency, automation and intelligence in the production of microchips in clean rooms. Semiconductor manufacturing industry has driven the technology for increased sensitivity in the field of gas and air sensors for early detection, prevention and safety and in the analysis in quality and monitoring of cleanrooms. R&D continues driven by high tech innovation of integrated circuits, miniaturization, integration of technologies, Wi-Fi communications, and automation.

Innovative Intelligent Thermostats

Recently major companies like Honeywell and Siemens are applying their technologies on new markets and further developing modern, innovative and intelligent commercial room thermostats for homes, buildings, and hospitals, providing an excellent reference of technology transfer and new possibilities for modern intelligent operations.



Figure 3. Intelligent thermostats: Nest, Honeywell TB8220U1003, and Network Thermostat UP32-WIFI.

These advanced programmable thermostats include Powerful User Controls, automation and interactive with heating & cooling systems, smart learning and history, wireless connectivity, Internet, remote control, iPhone app, and several other features. Fig. 4 shows three advanced