From Distant Galaxies to Global Markets: Determining the Value of Technology

By Dennis Senik, Doyletech Corporation

How can astronomy justify the huge cost of observing distant galaxies to watch the formation of new solar systems? That's the question we answered for NRC: to show how the $250 million expense for Canada was well worth it. To enable the telescope's scientific mission required NRC's Herzberg Institute for Astrophysics to develop some highly sophisticated technology. To understand how it could be applied in industry, we launched a series of discussions with the scientific and engineering team. The goal was to shed light on five key questions:

Canada will pay nearly $250 million over the next decade to help build the world's largest telescope in Hawaii. The TMT is a joint initiative with the United States, Japan, India, and China. The TMT can observe planets that orbit distant stars and enable astronomers to watch new planets and stars forming. Its images will be 10-100 times clearer, depending on the observation.

The Thirty Metre Telescope (TMT)

- What does the technology do?... and how?
- What remains to make it fully operational?
- Who cares?... and what's it worth to them?

Of the many technologies developed by the astrophysics team, we focused on six. Our technical and market research determined their total receptor markets to be worth US$465billion in 2014, growing to US$665 billion in 2019. Below we outline the results for the blockbuster technology of *adaptive optics*.

Adaptive Optics (AO): What and How

Look across a parking lot on a hot day; distant objects seem to shift and dance. So does starlight: it 'twinkles'. AO corrects this distortion. An analogy is an ocean wave. It starts out perfectly straight far at sea, but when it reaches shore it has been distorted by wind, currents, and rocks. For every point on the now-ragged wavefront to reach shore at the same time, the shoreline would have to be bent to match the wave's distortions. AO does exactly that, literally reshaping the shoreline (a flexible mirror) such that the reflected wave is made perfectly straight again.

AO uses a high speed sensor to measure incoming wavefront distortions by comparing them with a reference source. A fast computer then drives actuators to reshape the flexible mirror hundreds of times each second to compensate.

THE TECHNOLOGY; WHAT IT DOES, AND HOW

Distant starlight is distorted by its passage through the earth's turbulent atmosphere. By the time light reaches an image capture device at the focal point of a ground-based telescope, far-away stars look like hazy blobs. Because of this, even the largest telescopes have no better image resolution than an 8-inch hobby telescope. Adaptive Optics (A0) undoes this distortion to make the image crystal clear again.

WHAT REMAINED TO MAKE AO OPERATIONAL?

AO was a brainchild of astronomy in the 1950s. But it took significant developments in computing and rapid actuation of flexible mirrors to realize its promise. The first systems were secretly built by the U.S. military to image Soviet satellites in the wake of the Cuban Missile Crisis (1962). By the late 1980s, Canadian and European astronomers had built greatly improved AO systems using key commercial components developed by French companies. This work made Canada a world leader in AO systems.

But the Thirty Metre Telescope required even better performance. NRC's team developed prototypes integrated with all supporting systems and demonstrated them under real operating conditions. In market applications, these AO elements would become part of customers' larger systems. But where were the paying customers?

WHO CARES?

In brief, anyone who needs to improve the images produced by optical systems; in particular, AO can correct the distortion caused by any medium through which light travels to an image capture device.

Our research of over 120 scientific papers, scores of trade publications and industry reports detailed five major applications in the emerging AO market:

- **Defence and security**, e.g.: to continuously refocus powerful laser beams to destroy incoming missiles at distance.

- **Communications:** wireless networks often employ a laser link for free-space point-to-point communications over short distances. AO corrects the beam for atmospheric distortion.

- **Manufacturing and industrial quality control:** beam controls for laser welding and cutting are the largest macro applications; marking and engraving are the largest micro uses.

- **Biomedical imaging** has two major applications:
  Ophthalmology: for retinal imaging and measurement of visual function
  Microscopy: tissue structure introduces complex image aberrations that accumulate with depth; to further complicate things, light is distorted twice, travelling to the target, then back to the receiver. However, AO can correct this to allow in vivo observation – the Holy Grail of microscopy.

- **Consumer applications** are huge:
  Digital still cameras and camera-equipped mobile phones are longer-term applications that will benefit from cheap AO systems.

  Corrective vision using AO allows compensating for all of the errors in the eye's optical system, both lower and higher order, to achieve hitherto unavailable 'perfect' (diffraction-limited) vision.

AND WHAT'S IT WORTH TO USERS?

Presently, AO systems barely register: global sales of US$140 million in 2013. But while new to industry, AO is highly developed from 25 years of astronomy applications. With this head start, AO sales will reach over US$40 billion by 2022.

THE BOTTOM LINE

Just as real estate's value is location, location, and location; technology's worth is applications, applications, and applications. Figuring out what they are and who can benefit depends on understanding what the technology can do and how it works. The rest depends on assessing recent events and appreciating the important back story of technology's secret life in other domains before reaching industry. And, of course, appreciating the choreography that the *s-curve* brings to market penetration is essential in peering ahead.

AO systems are about to shift gears into the exponential growth phase.

EDGE BY DOYLETECH CORPORATION

is a series of articles that explore how technology is reshaping the economy and serves to better inform decision making in business and government.

www.doyletechcorp.com
Contact: Glenn McDougall
613.226.8900 x13