Landsat: Yesterday, Today, and Tomorrow

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Abstract

Landsat, first placed in orbit in 1972, established the U.S. as the world leader in land remote sensing. The Landsat system has contributed significantly to the understanding of the Earth's environment, spawned revolutionary uses of space-based data by the commercial value-added industry, and encouraged a new generation of commercial satellites that provide regional, high-resolution spatial images. This PE&RS *Special Issue provides an update to the 1997 25th Landsat anniversary issue, particularly focused on the contribution of Landsat-7 to the 34+ year history of the Landsat mission. In this overview paper, we place the Landsat-7 system in context and show how mission operations have changed over time, increasingly exploiting the global monitoring capabilities of the Landsat observatory. Although considerable progress was made during the Landsat-7 era, there is much yet to learn about the historical record of Landsat global coverage: a truly valuable national treasure. The time to do so is now, as the memories of the early days of this historic program are fading as we speak.*

Introduction

Approximately 40 years ago, William T. Pecora had a dream. In a decade when most of the space industry and science community centered its attention on getting man to the moon and looking outward toward the universe beyond, Pecora felt that perhaps we ought to look in the mirror with some of our technological advances and at ourselves to learn more about the dynamics of our own planet as influenced by natural events and human activities. What evolved from that dream is what we know today as the Landsat series of Earth observation satellites.

The modern era of terrestrial satellite remote sensing was inaugurated in July 1972 with the launch of the first Landsat (then called Earth Resources Technology Satellite, or ERTS). Landsat-1 pioneered the use of space platforms for systematic collection of land images (Short *et al.*, 1976). These repetitive measurements have produced a virtual revolution in terrestrial research, revealing the importance of medium-to-high spatial resolution, multispectral measurements for monitoring biospheric processes and demonstrating the value of tracking the seasonal and interannual evolution of land-cover conditions anywhere on the globe (Kauth and Thomas, 1976; McDonald and Hall, 1980; Tucker, 1979) (Plate 1). Most recently, on 15 April 1999, Landsat-7 was launched to continue the fulfillment of this dream, to carry on the mission of continuous monitoring and discovery of our terrestrial home at the human scale (Goward *et al.*, 2001).

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Our experience over the first several years of the Landsat-7 mission has shown that after adjusting for cloud cover interference, instrument duty cycle limitations, and other image acquisition constraints, a single Landsat satellite is barely capable of global and seasonal coverage (Arvidson *et al.*, 2001). Clearly, improved coverage could be obtained if there were multiple satellites in orbit so as to reduce the number of days between subsequent overpasses. Nevertheless, the database of Earth observation imagery resulting from Landsat-7 and its predecessors is unmatched in quality, detail, coverage, and value. The fact that nearly 40 other Earth-observation missions have been launched or planned internationally in the intervening years speaks to the overall success and importance of the Landsat program (Stoney, 2006) (Plate 2).

Global Change: The Role of Landsat

Over the last quarter century, U.S. and international scientists have increasingly focused on improving our understanding of the Earth's environmental systems (Bretherton, 1988). Measurements of atmospheric chemistry and models of the global climate system suggest that changes have occurred in the Earth system over the last century. These changes are continuing today, and may alter environmental conditions over the next century (Hansen, 2004). Initial efforts to estimate how the Earth might change over the next century confirmed that the current understanding of Earth systems is incomplete (National Research Council, 1993). For example, the annual atmospheric CO_2 budget cannot be balanced, with about 30 percent of the budget not completely understood. Linkages between land conditions and atmospheric dynamics are poorly defined and rarely specified in planetary climate models. The role and dynamics of human activities within the Earth system are only beginning to be investigated but appear to be a major source of Earth systems change (Houghton, 1999; Sarmiento and Wofsy, 1999). An integrated understanding of how the various elements of the Earth system (i.e., climate, hydrology, biospheric processes, and human activities) interact to produce environmental conditions is clearly needed.

Landsat was one of the major forces leading to the development of the global-scale Earth Systems Science concept, the International Geosphere-Biosphere Program (IGBP), and the U.S. Global Change Research Program (USGCRP) (National Research Council, 1983). In the mid-1980s, after a decade of Landsat research, it became evident that satellite remote sensing could provide the type of globally consistent, spatially disaggregated, and temporally repetitive measurements of land conditions needed to describe terrestrial systems (National Research Council, 1993).

Early research using Landsat data demonstrated the significance of the spectral vegetation index measurements as

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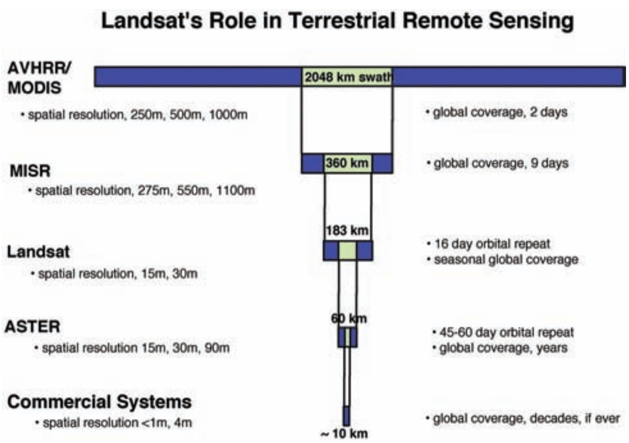

Plate 1. Landsat's medium resolution is well-suited to systematic global coverage.

a record of vegetation conditions (Jackson, 1983; National Research Council, 1986; Tucker, 1979). This index of green foliage density is a fundamental attribute of the landscape, describing the absorption of sunlight, photosynthetic capacity, and evaporation rates. These physical and biological processes are primary descriptors of how land conditions modulate the Earth system (Sellers *et al.*, 1995). Once it was understood that space-based Earth imaging could provide such information about land patterns and dynamics, the possibility of developing fully integrated land-ocean-atmosphere monitoring and modeling capabilities was realized. Landsat image data provide one of the most important elements of Earth observation needed to develop the concept of Earth Systems Science (Goward and Williams, 1997)

Conclusion

The digital image data provided by the Landsat series of satellites over more than 34 years are one of the most valuable scientific assets available to the Earth science user community. Indeed, Landsat data have done as much to solidify the concept of Earth systems science over the past two decades as any other single source of terrestrial information. These data provide the most consistent, reliable documentation of global land-cover type and land-cover change over the past three decades.

The work presented in this *PE&RS* Special Issue on Landsat provides an update on efforts to maintain and increase the quality of the Landsat observation record through the Landsat-7 mission. Hopefully, the lessons learned in this decade will continue to influence land remote sensing scientists and engineers in the decades to come.

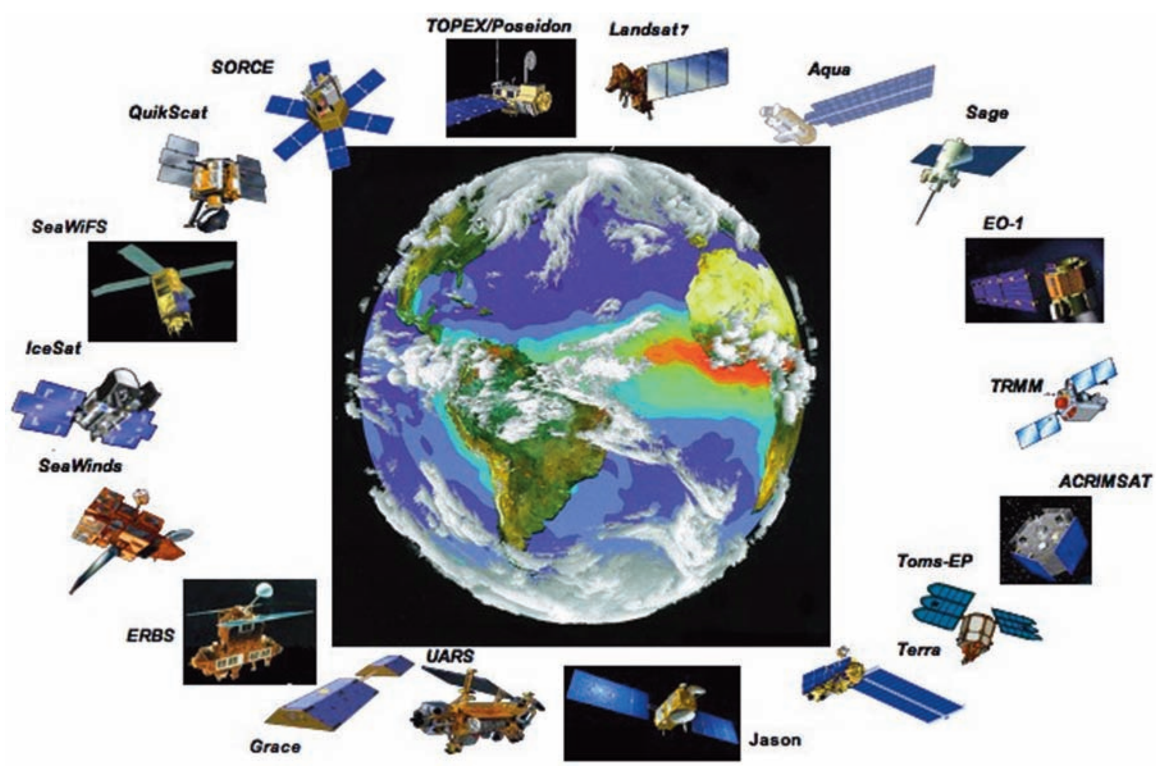

Plate 2. Some of the more than 40 Earth-observing satellites providing global measurements.