A Small-sat Mission Concept to Enhance Global Temporal Repeat Coverage at Landsat-like Resolution

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Overview

The 38-year Landsat archive constitutes one of the most valuable global change data records available to the world. Landsat images have documented land cover and land use change spanning a period when global populations more than doubled, and associated land transformations have increased at a dramatic rate. Although the availability of recently free Landsat imagery has heightened the interest in increasing the temporal frequency of such valuable observations, the prospect of improving upon, or even maintaining, the 8-day temporal repeat coverage of the last decade from Landsat's 5 and 7 will be hard to realize given the escalating costs of building and launching such observatories (i.e., ~ $1B). There is a need to look for dramatically lower cost options to augment, but not replace, these classic Landsat missions.

We have taken a fresh look at developing a scientifically useful low-cost imaging concept. Our goal is to derive cost-effective alternative solutions that can provide imagery of sufficient quality and quantity to augment global Landsat coverage and mitigate single point failure scenarios that could cause long gaps in Landsat-like coverage. We call our effort **LOGICAL**, short for **L**and **O**bservations **G**lobally **I**n a **C**ost-effective ***Augmentation*** of **L**andsat. Independent reviewers of the concept have described it as "innovative," and preliminary findings indicate that such a mission is doable at a cost that is as much as an order of magnitude less expensive than a typical "gold standard" Landsat mission in today's aerospace environment. If such an augmentation mission concept could be realized, the dream of having access to a weekly to bi-weekly cloud-free global product at 30m could become a reality. Such robust data sets would not only serve to dramatically enhance Earth science applications, but it would also reduce the risk of a devastating gap in Landsat-like imaging capability.

A Low-cost Earth Observation Mission Concept

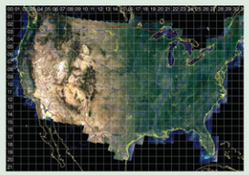
The goal of the LOGICAL concept is to derive cost-effective alternative solutions that can provide imagery of sufficient quality and quantity to augment global Landsat coverage and serve as a back-up to standard "flagship" missions to avoid single point failure scenarios; we desire to accomplish all of this for ~1/10 the cost of a typical Landsat mission, which now costs close to $1B.

Background / Rationale

- Landsat's 16-day revisit, when coupled with cloud-cover, translates to seasonal, or even annual mapping, at best, for much of the globe.
- Such sporadic "seasonal" mapping cannot support applications that require more frequent observations at Landsat spatial resolution.
  - Agricultural monitoring (global food security)
  - Rapid identification of forest clearing/disturbance (carbon/UN REDD*)

  **REDD = Reducing Emissions from Deforestation and Forest Degradation – A UN Program*
- Understanding vegetation dynamics requires characterizing within-year seasonality. For best results, one needs clear views ~ once per week during the growing season.
- Landsat (LDCM / Landsat-9) continues as a "single-point failure" program; although declared "operational" by OSTP, a launch failure of LDCM could open a 5+ year hole in Landsat continuity.

> ***"Already, U.S. capabilities no longer meet the increasing demand for frequent, high-quality multispectral imagery. Furthermore, it is already known that many U.S. users would benefit from global land coverage as frequent as every 2-4 days. Yet, expanding the number of U.S. satellites deployed might be prohibitively expensive."***
>
> *-"A Plan for a U.S. National Land Imaging Program," issued August 2007 by OSTP*
>
> **Conclusions:**
> As Landsat missions start to approach and exceed $1B, we also need lower-cost solutions to improve temporal coverage and insure against lengthy data gaps.



WELD Tile Map (CONUS has 501 tiles in Albers)
Courtesy of **Dr. David Roy**, *South Dakota State University*

A goal of LOGICAL is to enhance temporal repeat cycles to the point where weekly to bi-weekly cloud-free mosaics for large regions can be generated using the existing Web Enabled Landsat Data approach (aka "WELD").

The WELD approach is used to generate 30m composites of Landsat terrain corrected mosaics at weekly, monthly, and annual periods for the continental US and Alaska. These mosaics provide consistent data that can be used to derive land cover as well as geo-physical and biophysical products for regional assessment of surface dynamics and to study Earth system functioning. With LOGICAL, we propose to expand this concept to all global land masses.

LOGICAL Concept

Continue Landsat-7/LDCM/Landsat-9 missions as calibrated "Gold Standards" and augment the temporal coverage richness using low-cost LOGICAL satellites – kind of a "Mother Hen and her chicks" approach. We plan to use the reduced spec metrics derived by the Landsat Data Gap Study Team (2007) as a starting point, then push each parameter toward "gold standard" spec, while looking for the "knee" in cost curve.

Performance Parameter	Performance Goal: LDCM Specification	Baseline Specification[1]	LOGICAL Start Points
Spectral Banks[2]	Blue: 350-515 nm Green: 525-600 nm Red: 360-680 nm NIR: 845-885 nm[3] SWIR(1): 1560-1660 nm SWIR(2): 2100-2300 nm	Green: 525-600 nm Red: 630-680 nm NIR: 845-885 nm[2] SWIR(1): 1560-1660 nm	No blue band No 2.2 μm band No TIR band
Radiometry	< 5% error in at sensor radiance, linearly scaled to image data	< 15% error in at sensor radiance, linearly scaled to image data	
Spatial Resolution	30m GSD VNIR-SWIR; 15m panchromatic	10-100m GSD	Will insist on 30m
Geographic Registration	< 65m circular error	< 65m circular error	
Band-band Registration	Uncertainty < 4.5m (0.15 pixel)	uncertainty < 0.15 pixel	
Geographic Coverage	All Land areas between ± 81.2° north and south latitudes, including islands, atolls, and continental shelf regions of less than 50m water depth	All Land areas between ± 81.2° north and south latitudes at least twice per year	Will insist on Landsat like global coverage

Surrey Satellite Technology (SST)-US: An example of a one vendor end-to-end solution for both instruments and satellite

- 34 successful "Small Sat" missions with 200+ years on-orbit experience; last 10 yrs they have 100% mission success.
  - 8 additional satellites, some with Surrey payloads, currently under contract / in development
- Surrey's Disaster Monitoring Constellation (DMC)
  - 7 operational satellites to date
  - 3 - 4 bands, 600km swath @ 20-30m resolution
- SSTL-150 bus currently in Goddard's RSDO catalog @ $16.5M
- Initial discussions indicate feasibility of a Firm Fixed Price contract* for 2-camera (VNIR/SWIR) system for LOGICAL:
  - 300 km swath width
  - 22 m resolution VNIR & ~45 m SWIR
  - **Total estimated cost, in orbit + 1 year ops, for two satellites < $100M***

** Firm Fixed Price assuming Surrey's proven processes are used. Adherence to all NASA requirements may inflate this quote by as much as 50%.*

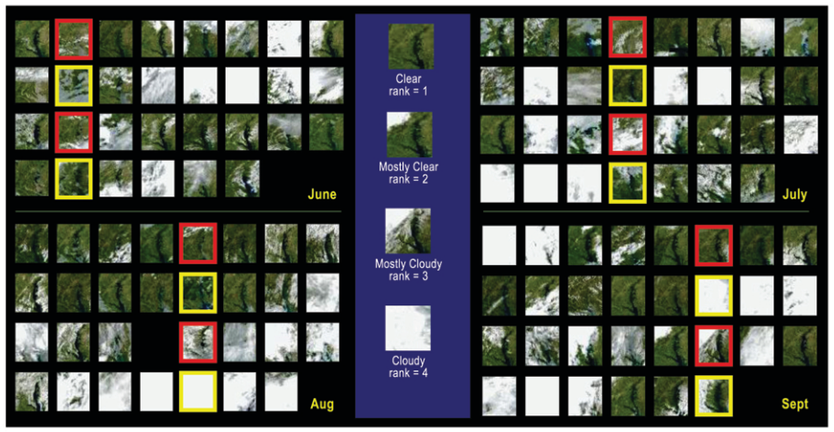
Example of DMC MSI Imagery

What Temporal Repeat Frequency Is Needed To Create Cloud-free Mosaics?

- An Assessment of MD/VA Daily Cloud Cover Using MODIS "Landsat-sized chips" for 2002 growing season months – June, July, August & September.

NOTE:
"8 day / week" calendar being shown due to 8-day repeat with Landsat's 5 and 7 orbits; images highlighted by red and yellow border correspond to actual Landsat 5 and 7 observation dates.

- Visual assessment of cloud cover in MODIS "Landsat sized" chips (see center column)
- Each image assigned rank of 1 - 4 based on cloud cover in chip. Over an 8 yr period, 2001-2008, we assessed the ability to create a cloud-free mosaic product if we had 1 day repeat coverage, 2 day repeat, and so on.
- On average ~ 12 weeks out of 15 possible clear views via daily repeat coverage.
- On average ~ 9 weeks out of 15 possible clear views via 2-day repeat coverage.
- We obtained similar results for NW Pa and central Indiana.



Closing Statement of Clarification

- The LOGICAL mission concept is intended as an augmentation, not a replacement, of the classic Landsat flagship mission that the world has come to respect, admire and love.
  - Such "gold standard" flagship missions must continue and serve as the primary workhorse.
- However, the high cost of these flagship missions, now approaching $1B, are a hindrance to building such missions in sufficient numbers to provide the more frequent temporal repeat coverage needed to defeat cloud cover, or to avoid on-going threats of long gaps in critical global coverage due to a single mission failure.
- We have developed a LOGICAL concept solution that we are confident can provide imagery of sufficient quality and quantity to augment global Landsat coverage – at a cost that is approximately an order of magnitude less than the estimated cost of the Landsat 9 mission slated for launch no earlier than 2017.

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