LOGICAL Concept

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Land Observations Globally In a Cost-effective *Augmentation* of Landsat

A low-cost small sat mission concept to provide: (1) the temporal time domain for Landsat-like global coverage needed for time sensitive uses of the data (e.g, ag productivity & disaster management), and (2) to serve as a "gap-filler" in global coverage at Landsat-like resolution to resolve on-going "data continuity" / single point failure concerns.

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Statement of Clarification

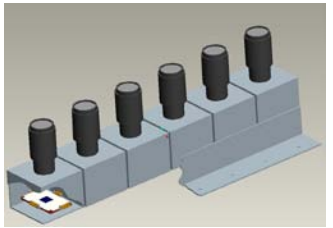
- **The LOGICAL mission concept is intended as *an augmentation, not a replacement*, of the classic Landsat flagship mission that the world has come to respect, admire and love.**
  - Such "gold standard" flagship missions must continue and serve as the primary workhorse, covering all portions of the EM spectrum, including the TIR.
- However, in my opinion, the high cost of these "gold standard" flagship missions, now approaching $1B, yes "B" as in billion, are a hindrance to building such missions in sufficient numbers to provide the more frequent temporal repeat coverage needed to defeat cloud obscuration, or to avoid on-going threats of long gaps in critical global coverage due to a single mission failure.
- **The goal of the LOGICAL concept is to derive some *cost-effective alternative solutions* that can provide imagery *of sufficient quality and quantity to augment* the global Landsat coverage and serve as a back-up to avoid single point failure scenarios.**

LOGICAL Mission Concept

A Top Level Overview

- **Concept:** Develop low-cost, "small sat" broad area coverage, ~30m instrument and mission concepts to: **(a)** enhance temporal time domain of Landsat-like global coverage, and **(b)** resolve on-going Landsat single point failure issue.
  Use Landsat Data Gap Study team "spec's" to drive design decisions; push toward LDCM spec's, look for knee in cost curve.
- **Approach:** Multi-faceted: **(1)** in-house GSFC instrument build & use an RSDO* satellite bus; **(2)** get instrument via an industry competition & mate it to an RSDO satellite; or **(3)** total end-to-end solution via industry competition [e.g., such as Surrey Satellite Technology (SST) US & their Disaster Monitoring Constellation (DMC) MSI sensor].
- **Co-I's / Partners:** Williams (GST); Masek & Tucker, GSFC/614; others TBD

- **TD* 30m multi-camera** concept by Tucker/Shu'09: 6 camera's, each 640 x 512 InGaAs array, 5 beam slices per camera, 96 km swath ea, 0.4 - 1.7 μm spectral cover
- **SST US DMC MSI** with ~30 m, 600 km swath, in TM bands 2, 3, and 4; **would need to add TM 5**



- **Initial plan is a 3 phase approach/schedule:**
  Phase I => May thru Aug to put more meat on bones, meet with USGS & NASA rep's, meet with potential industry partner(s); prepare/submit unsolicited proposal to NASA
  Phase II => Sept thru Dec 2010 conduct more in depth systems engineering & costing analyses while proposal is in review
  Phase III => CY2011 to get to Phase A assuming influx of some government funding

*RSDO = Rapid Spacecraft Development Office at NASA Goddard / TD = Time Domain

Background / Rationale

- In 2006, Marburger @ OSTP initiated an inter-agency effort to develop a long-term plan to achieve technical, financial and managerial stability for operational land imaging => resulted in “Future of Land Imaging Interagency Working Group” that developed “A Plan for a U.S. National Land Imaging Program,” issued in August 2007.

- The Executive Summary of “The Plan” highlighted the following:

  - ***The U.S. Landsat satellite series holds a position of unique and unparalleled importance in the world.***

  - ***Even with immediate action, the U.S. anticipates a gap in Landsat data for an unknown period of time.***

  - ***U.S. capabilities no longer meet the increasing demand for frequent, high-quality multispectral imagery.***

Sense of Urgency

- The Executive Summary of the 2007 “Plan” also states:

Already, U.S. capabilities no longer meet the increasing demand for frequent, high-quality multispectral imagery. LDCM will provide data over the United States once every 16 days, the same rate as each of the current Landsat satellites. However, this 16-day revisit time will cause a decrease in U.S. land imaging coverage as compared to the 8-day repeat cycle that results from the staggered orbits of the two existing Landsat satellites. Furthermore, although a comprehensive assessment of user requirements is needed and must be conducted, it is already known that many U.S. users would benefit from global land coverage as frequent as every 2-4 days, particularly for time-sensitive uses in agriculture, disaster management, and national and homeland security operations. Yet, expanding the number of U.S. satellites deployed might be prohibitively expensive.

Conclusion: Need lower cost solutions as soon as possible.

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Sense of Urgency *(cont)*

- The following was extracted from an April 14, 2010 letter from Dr. Curtis Woodcock, Team Leader of the USGS-funded Landsat Science Team, to the new USGS Director, Dr. Marcia McNutt:

"I write to offer the support and encouragement of the Landsat Science Team at this critical time for our nation's land remote sensing programs. … The Landsat Program has provided a continuous record of imagery of Earth's surface since 1972 and the accumulated archive of imagery is among our most precious environmental records. … (but) "… the strength of the ... Program, continuity of observations, is in jeopardy! The good news is that there is continued encouraging progress on the building of the LDCM, due to launch in late 2012. The bad news is that there are no plans for satellites beyond LDCM and the process of Congress authorizing and appropriating the funds, and subsequent building a satellite system is lengthy. For example, LDCM was authorized by Congress in 1999 and won't launch until 2012. Since LDCM has a design life of five years, it is imperative that we begin immediately with the follow-on to LDCM."

Conclusion: Need to act now -- conventional solutions take a lot of time.

LOGICAL Concept / Approach

- The LOGICAL concept is to develop a low-cost alternative approach to acquire Landsat-like broad area coverage that are of sufficient quality and quantity to serve as a viable back-up to a normal Landsat mission, while also improving the temporal repeat coverage of global Landsat-like data.

- We plan to use, as a set of guidelines, the outcome of the **Landsat Data Gap Study Team** that issued their final report in Jan 2007. The Team was a multi-agency group of scientists and data end-users that looked at all current and near-term future Landsat-like missions for data that could marginally fill the gap in global coverage if both Landsat 5 and 7 were to became inoperable before LDCM was launched. They developed a set of instrument performance / data product specifications that would be minimally acceptable to them as a viable Landsat gap filler data set, and then compared those to the current LDCM spec's (e.g., they said spatial resolution between 10 – 100m would would be acceptable, but they had strong preference for 30m or better). Our approach will be to use their minimally acceptable set of spec guidelines and then see which spec items can be driven toward meeting the more stringent LDCM spec before breaking the bank ***(i.e., where is the knee in the cost curve for each spec parameter?).***

LOGICAL Concept / Approach

Baseline Performance Specifications from Landsat Data Gap Study Team

Performance Parameter	Performance Goal: LDCM Specification	Baseline Specification[1]
Spectral Bands[2]	Blue: 350-515 nm Green: 525-600 nm Red: 630-680 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
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
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

LOGICAL start points

No blue band,
No 2.2 um band,
No TIR band

Will insist on 30 m

Will insist on LTAP-like global coverage

[1] Acquired data must be characterized & verified against these specifications to ensure data quality & continuity.

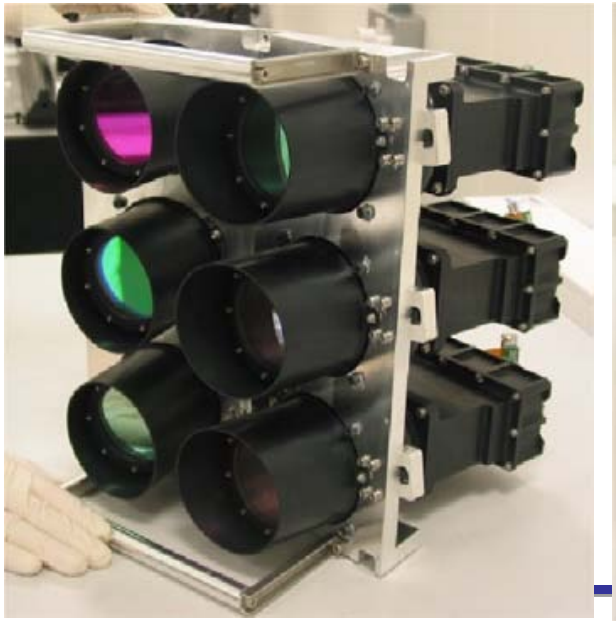
With these guidelines in mind, I started poking around on the internet.

Surrey DMC MSI Instrument

A potential "one vendor" satellite & sensor solution

WIDE SWATH DMC MSI (following extracted from their website)

The Disaster Monitoring Constellation (DMC) Multispectral imager (MSI) is a pushbroom imager that has an effective sensor length of 19,500 pixels for each of its three separate waveband channels (would need to be modified to add TM band 5). At an orbital height of 686km this yields a 600km swath width for each image. Surrey states that MSI imagers are performing successfully on the Alsat-1, UKDMC, Nigeriasat-1 and Beijing-1 spacecraft in the DMC. Each 600 X 500 km image generates ~ 1 GByte worth of data. (Two more already built and launching soon).



Imager overview.

The pictures to the left are of the Wide Swath DMC MSI, consisting of 6 channels, 2 banks of 3. Each bank is mounted at an angle to each other so that they image adjacent parts of the ground scene. These opposite pairs of channels each have a 10,000 pixel linear CCD sensor and identical filters, giving an effective image width of 19,500 pixels for each of the 3 chosen wavebands. There is an overlap of 500 pixels between banks to ensure image continuity.

Who Is Surrey?

Not exactly "newbies" in Earth observation

- Quoting from their website, "Surrey Satellite Technology (SST) has launched 34 satellites gaining almost 200 years in-orbit experience. SST draws on its world-class expertise in both small satellite platform technology and high and medium resolution imagers. SST provides complete turnkey system solutions: spacecraft, ground station, launch, operations, and image data processing."

- Instrument and mission costs for current DMC MSI configurations are well known to Surrey as they have already flown several in space. To implement LOGICAL, one would have to factor in such things as:
  - **Cost to add TM band 5 capability**
  - **Cost to bring heritage instrument performance up to Landsat-like standards**
  - **Cost of additional on-board storage and data handling capability to match Landsat's robust data acquisition strategy**

Cost Goal and Obstacles Ahead

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The cost goal is to come up with a concept with believable end-to-end mission costs, with contingency factored in, that are approximately an order of magnitude less than "gold standard" Landsat 7 and LDCM mission costs.

We need Science Team and community support – let's not circle the wagons and shoot inward.

- need to understand & appreciate that decent data all the time (to "mine" the temporal domain) to augment "slam dunk" gold standard data that may have significant gaps in coverage (due to single point failure)

However, there is no current funding niche for this type of mission

- it's not a Decadal Survey mission
- I don't think it currently qualifies as a Venture Class mission

It would probably have to be sold as a "Mission of Opportunity" to NASA HQ

- NASA is the logical agency to fund much of this as USGS, just like NOAA, would only be expected to fund proven operational missions

Also need to explore some new, innovative funding approaches. For example, maybe a very attractive Firm Fixed Price for a sensor, satellite, & launch package, in exchange for a signed contract to provide monthly stipends for unfettered data acquisition & downlink.

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Next Steps

- Will be meeting with Surrey US rep's this Friday to begin dialogue to: (a) better understand their existing sensors, satellites and data handling capabilities, and

  (b) for them to better understand what it means to develop a sensor and platform system capable of delivering Landsat-like performance.

- Depending on the outcome of those discussions, we will decide whether we will prepare/submit an unsolicited proposal for submission to NASA, or whether we punt.

- Any move forward will involve a full and open competition within the industry – we are not locked in to a Surrey US solution, but we needed someone with their low cost approach and positive track record to make our cost estimates credible.

- There should be no doubt that the US aerospace industry will definitely see this as a threat to business as usual & push back hard.