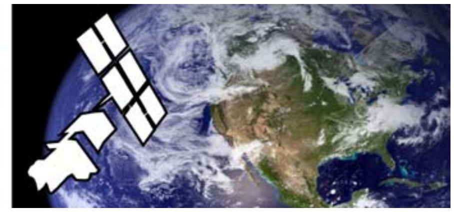

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January 20, 2004

Dear Colleagues (see list of presenters below),

Each of you has responded positively to my invitation to present your thoughts at a March 23rd meeting of the NASA Surface Water Working Group. I am truly appreciative of your time and energy spent toward this very important meeting of our working group. Thank You!

Your presentations will focus on spaceborne technology for an ESSP class mission targeting surface water (i.e., inland freshwater bodies such as river channels, lakes, reservoirs, wetlands, and floodplains). Through a modeling exercise known as a "virtual mission", the working group is in the process of determining the hydraulic variables that need measurement and identifying the required spatial and temporal samplings. We expect to complete the virtual mission later this year. For now, we do know that water storage changes are necessary and discharge is perhaps also required. The Perspective article in *Science* (see attached PDF) places these technology thoughts in a hydrologic science context and details why we believe an altimetric approach is the best current ESSP option. The following will also help guide your presentation thoughts.

Storage Change Measurements:

Storage change, ΔS, is a simple multi-temporal product of water surface area multiplied by its elevation. A temporal sequence of such measurements provides volumetric changes from one time acquisition to the next. Ideally, ΔS would be measured from topographic mapping technology (e.g., like SRTM) wherein water surface elevations would be measured for every pixel within an image. Such an approach would probably be too expensive for an ESSP proposal. Instead, it should be possible to use altimetry to measure water elevations along a profile and combine these with a commensurate image of the water area. The image could be acquired from a low-cost camera or from radar imaging methods. Although the elevations would only be known along the altimetric profile, their extrapolation across the image should be sufficient for our hydrologic science goals (the virtual mission will demonstrate the accuracies of this reasonable assumption). *Thus the hydraulic targets for ΔS are surface area and elevation collected over time.*

Discharge Measurements:

The conventional, in-situ approach to measuring discharge, Q, is the product of flow velocity multiplied by channel cross-sectional area. Attempting to replicate this measurement from space is not straightforward and, furthermore, ignores the great lateral-space advantage of the satellite perspective. Our virtual mission will determine if we can exchange this lateral-space for cross-sectional space as well as defining the importance of Q for answering our hydrologic questions. If Q is required, the flow velocity will be required. One possible approach to measuring velocity from space is with along-track interferometric SAR methods, but this may prove too costly for ESSP. Furthermore, such velocity measurements are necessarily collected from the water's surface where wind can induce erroneous velocities. Instead, we know from Manning's equation that the water slope can be reasonably used to empirically calculate the channel flow velocity. *Thus, the hydraulic targets for Q are slope and surface area collected over time.*

Known Problems:

Our surface water targets are often obscured by clouds and vegetation (and sometimes smoke). Furthermore, any off-nadir attempts can often result in specular reflections, especially for longer microwave wavelengths. The ideal instrument will be capable of providing measurements at every overpass, but perhaps a cost tradeoff may permit an instrument capable of canopy and cloud penetration on most overpasses, but not necessarily every occasion (the virtual mission will determine the tradeoff). For example, an optical camera may be lower cost than imagery derived from radar, but may not provide inundation area for every data take (whereas long wavelength radar penetrates clouds and canopy).

"Best Guess" on Temporal and Spatial Resolutions:

The *Science* Perspective lists these resolutions and our reasoning for their selection. However, I there is some room for variation. Please note that a primary goal of the virtual mission is to carefully identify these resolutions, thus the given values are "best guesses". I am also posting this letter on our working group web page (www.swa.com/hydrawg, click on "letters" button) to further solicit our colleagues for their thoughts.

The temporal resolution is probably dictated by the ~one month Spring melt that occurs across much of the Arctic. In a period of just a couple of weeks (no longer than a month), melt conditions provide almost all of the discharge in Arctic watersheds. Thus, a monthly temporal sampling is probably unacceptable, whereas daily samplings are likely too costly. *A reasonable accuracy should occur from weekly measurements at equatorial crossings resulting in say 3-day repeats near the poles.* The Amazon is another obvious target and, fortunately, its discharge variability allows for say monthly samplings (at the maximum). So, the temporal sampling range could extend to about a week at the poles with about 3 weeks at the equator, but I do not think we could stretch beyond that.

The spatial samplings are separated into altimetric and imaging categories. *Elevation measurements might be required for channels that may be only ~100 meters in width*, thus altimeters should be capable of providing an elevation every ~100 meters along the profile. We do not believe that smaller channels will be targeted. There may prove to be some range to this requirement, but we doubt that elevations every ~250 m will be sufficient. *The elevation accuracy needs to be at least 10 cm, and 5 cm would be better.* River slopes in the Amazon are among the lowest at 1 cm/km, thus a 5 cm accuracy would require a slope calculation across a 5 km reach. For the imaging, the virtual mission may demonstrate that lower resolutions of about ~500 m pixels are capable of providing the storage change measurements. However, discharge measurements in ~100 m wide channels may require smaller pixels. A tradeoff may exist for imagers wherein lower spatial resolutions coupled with cloud and canopy penetration may permit low cost radar methods.

Potential Instruments:

Given the topics listed above, we think an altimeter coupled with an image will provide the necessary hydraulic measurements. However, you may have a different approach to provide the hydraulic measurements; if so, please let me know.

List of Presentation Teams and Their Discussion Topics:

Notes: Please also include your thoughts on how to add an imaging capability to your technology. Also, let me know if you would prefer a different topic. The entire one-day meeting is dedicated to technology discussions, thus I am hoping you will have a generous amount of time to present your thoughts.

Radar Altimetry (Delay Doppler, e.g., ABYSS)
Keith Raney (Johns Hopkins APL)

Radar Altimetry (Wide Swath)
Yunjin Kim (NASA JPL)
Ernesto Rodriguez (NASA JPL)

Radar Imaging and Altimetry
Peter Hildebrand is assembling some thoughts (NASA GSFC)

Lidar Altimetry (e.g., GLAS):
Bob Schutz (U. Texas)
Melba Crawford (U. Texas)
Dave Harding (NASA GSFC)

This letter probably does not answer every question and, in fact, the details of the spatial and temporal sampling resolutions may change somewhat. Undoubtedly the science vs. cost tradeoffs determined by the virtual mission will provide more concrete targets. Thus, we remain quite open to an exchange of ideas. *The March 23rd meeting is not viewed as the final ESSP selection, rather it is a time to more fully understand our options. This meeting is essential; however, to the technology selection process and thus I truly welcome your participation (and am very grateful to you!).*

Sincerely,

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