THE LONGEST MEANDERING FLOODPLAIN ON MARS: THE AEOLIS MEANDERS

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Introduction: We propose a landing site at 5.84°S, 153.6°E, -2.35 km below the reference areoid. The meandering floodplains of Aeolis-Zephyria Planum (AZP) have received significant and sustained attention since their discovery [1-5]. Crosscutting levels of inverted channels logically require multiple episodes of valley incision and infilling. The presence of meanders also indicates a prolonged interval of fluvial activity. There are indications of floodplain deposits within the landing ellipse, which could trap fine-grained materials washed down from the dichotomy boundary. The meandering paleochannel is at least 175 km long. The floodplains are not an isolated occurrence but are the most-accessible members of a regional system of >150 inverted, meandering channels. In turn, these are type examples for sinuous ridges globally distributed across Mars [6]. There is also great interest in the nature of possibly volatile-rich Medusae Fossae Formation (MFF) materials [e.g., 7-9], which are accessible within the ellipse.

Therefore, multiple scientific inquiries could be undertaken and addressed by a rover within this ellipse, including but not limited to: sedimentology and 'grab-bag' clast analysis of channel materials constraining regional paleohydrology as a function of time; determining the meander stabilization mechanism; ground-truthing paleodischarge estimates from remote sensing [3,4]; seeking fine-grained materials (including organics) in overbank deposits, levees, and oxbow lakes; determining the nature of the cementation that allows the channels to be inverted; seeking evidence for past groundwater chemistry and pedogenesis; and determining the nature and origin of MFF materials.

Programmatic Context: Ancient climate, habitability and possible organic preservation are assumed to remain priority objectives of the Mars Exploration Program. Specifically, it is assumed that we seek to determine the duration, timing, magnitude and continuity of ancient fluvial activity and its role (if any) in forming aqueous minerals.

The proposed site is equatorial and low-elevation. We assume a rover with a range comparable to MAX-C and an instrument package built around field geology capabilities.

Science Merit Related to Mission Objectives:

Regional context: The meandering floodplains appear

to be amongst the most recent rivers to have flowed on Mars. The channels are exposed within the lower MFF. All available evidence suggests these >150 channels formed in the Late Hesperian - Amazonian [2], which is a challenge to the framework in which prolonged overland flow ceased shortly after the Noachian.

There are multiple lines of evidence that the Aeolis meanders formed over considerable time (>> decades). Throughout Aeolis, the inverted channels are themselves layered. The MFF outside the ellipse has been shown to have quasi-periodic bedding, as has Gale's central mound [10]. At least the upper Gale mound appears to be stratigraphically equivalent to MFF [9]. While not directly constraining the duration of fluvial activity, this sets the channel-forming process in a context in which sediment is accumulating over orbital (>10⁴ yr) timescales. As shown below, the geological evidence within the ellipse rules out formation by a transient event. Finally, meander formation and the river avulsion cycle on Earth are both prolonged processes, taking much longer than decades.

Volatiles at the landing site are suggested by gamma ray and radar data. At meter depths, MFF has the highest Cl and H concentrations on equatorial Mars, suggesting volatile activity. At 30-60m depths, MARSIS surface reflectivity results show all parts of MFF have a dielectric constant consistent with water ice [12], supporting subsurface sounding results over a more limited area [8]. However, the area has a high dust cover, and aqueous minerals have not been reported from CRISM FRTs in the MFF as of 2010 [9].

Ellipse suitability for proposed mission: Over the $\sim 10^5$ km area of inverted channels [2] in AZP, we are proposing one 20km–diameter ellipse for further imaging and detailed analysis (Figure 1). Our selection rationale is as follows:

(1) Sinuosity is unusually high for AZP and there are many cutoff loops. This raises the probability of finding oxbow lake deposits. Point bars and possible crevasse splay deposits have been identified. Therefore this is a good place to look for fine-grained materials, including organics, in overbank deposits and oxbow lakes. Terrestrial facies models of meandering rivers indicate that these fine-grained materials should exist [13]. Overbank deposits are considered a fairly good petroleum play in terrestrial exploration geology.

(2) Three of the meandering channels are overlain by

less sinuous inverted channels. This logically requires multiple cycles of infilling and fluvial incision. Thus, the observed geology requires multiple phases of aqueous activity and excludes a single transient event as responsible for the ellipses' geomorphology.

(3) Five channels run through the ellipse, so the target is an area of channels (2D) not a single channel (1D). The channels have modest relief (Figure 2), unlike other sites in AZP where our stereo DTMs indicate that the science target is itself a landing hazard (and difficult to approach).

(4) The existence of multiple paleochannels near each other raises an interesting question: did avulsion occur on Mars, or were multiple channels simultaneously active?

(5) Finally, the proposed ellipse is relatively smooth and yardang-poor by AZP standards, simplifying EDL and trafficability.

Extended mission options include going upriver (toward the source materials), downriver (the channel is >175 km long), or crossstream (in search of finegrained overbank deposits).

Insofar as layers with quasi-periodic bedding [10] are remobilized and modified by a rich array of fluvial processes, the Aeolis-Zephryia Planum site has similar facies to the similarly young SW Melas Chasma site. AZP might be considered a programmatic backup if Valles Marineris chasm slope winds continue to exclude spacecraft from SW Melas Chasma [14].

Engineering Constraints:

Latitude and elevation are within MER, MSL, and MAX-C limits. Ellipse diameter is conservatively set to 20 km. The abundance of HiRISE-resolveable boulders appears to be extremely low. The site is outside the 'stealth' region of low radar reflectivity. So far the only candidate landing sites at which mesoscale models have predicted unacceptably strong winds have been those with high topographic relief: this experience leads us to expect that winds will not be limiting at this low-relief site.

Although long-baseline slopes are typically <1°, the proposed ellipse exceeds the MSL User's Guide short-baseline slope constraints. This is because of the presence of yardang flanks of slope 10-25°. <u>Slope data</u> from our preliminary HiRISE DTM show that 12.0% of slopes are steeper than 15° and 0.6% of slopes are steeper than 30°, for the portion of the DTM within the proposed ellipse. We speculate that future landers could make landings on slopes >15° less hazardous than in the MSL User's Guide. Additional stereo is requested to allow future landing site selection panels to know what they are flying into.

A secondary concern is the low thermal inertia of the AZP region, which may indicate that the soils are not load-bearing. Quantitative thermal inertia analysis is needed to address this concern, but we do not expect additional THEMIS images would be required for this analysis.

Information Required for Potential New Landing Sites:

Landing Ellipse:

Table 1: Summary of p	loposed future landing site.
Site Name	Aeolis Meanders
Center Coordinates	5.84°S, 153.60°E
Latitude, longitude	
Elevation	-2.35 km (HiRISE DTM
	tied to MOLA)
Ellipse Size	20km diameter
Prime Science Targets	Possible oxbow lakes and
	floodplain overbank de-
	posits [Highest Priority],
	Channels,
	MFF materials [15]
	[Lowest Priority]
Distance of Science Tar-	Possible oxbow lakes +
gets from Ellipse Center	possible overbank depos-
	its $+$ channels $-$ 1.5 km to
	SSW
	MFF materials – 1.5 km
	to SW (in yardangs)

Table 1: Summary of proposed future landing site.

Rationale for Images: Additional data are requested to support science analysis as a prospective landing site, and quantitative safety assessment.

What would we learn about Mars from landing at Aeolis? (a) <u>Paleoclimate</u> - Local hydrology constrains global climate conditions; (b) <u>Habitability</u> - Duration and intermittency of fluvial conditions; (c) <u>Preserva-tion</u> - Overbank deposits are a candidate for preserving fine-grained materials, including organics.

The rationale for the Aeolis meanders as a landing site is that they formed under Earthlike flows and flow durations (cubic meters per second over thousands of years). Therefore, the additional images are designed to test this rationale.

What will we learn about Aeolis from additional images? (1) Regional hydrology. Does this drainage basin follow Earthlike scaling laws? (2) Slope, and slope-sinuosity relation, of meandering channels. Do

they resemble more closely alluvial meanders, bedrock meanders, or supraglacial meanders? (3) Relationship between parallel meander belts. Were these flowing at the same time? Is there evidence for avulsion? This requires HiRISE images of confluences. (4) HiRISE stereo is required to determine layer orientations, stratigraphic separation (if any) between adjacent floodplains, and stratigraphic thickness spanned by channel-bearing sedimentary package. (5) Do overbank deposits exist? HiRISE is needed to seek crevasse splay deposits and other indicators of meander cutoff overbank deposition. (6) Map margins of ellipse. Look for additional channels that we know are missed by CTX. Determine regional drainage density.

Therefore, we request (1st priority) HiRISE stereo coverage across the ellipse (4 additional pairs). If this cannot be achieved, we request 2 additional pairs (shown in dotted orange on Figure 1) to maximize stereo coverage for hazard assessment. Regardless, we request (2nd priority) HiRISE mono coverage across the ellipse. Next, we request (3rd priority) additional HiRISE images of the channels downstream (NW) of the ellipse to quantify changes in channel morphometry with increasing drainage area. The goal here is to constrain drainage basin hydrology. Coordinates of these additional images correspond to HiWISH requests 48342, 50182, 50184, and 55515. Finally, we also request (4th priority) 1 additional CRISM FRT within the ellipse.

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Figure 1: Example 20km-diameter ellipse on CTX mosaic at the Aeolis meanders. The ellipse is centered at 5.84°S 153.6°E at an elevation of -2.35 km. The prime science targets are the channels, shown in green, and immediately adjacent possible overbank deposits and possible oxbow lakes. Only one channel thread is shown per floodplain. Many floodplains have multiple channels. Paleoflow direction is from SE to NW based on meander asymmetry, present-day slope, and sense of channel width increase. Existing HiRISE coverage shown in orange. Existing CRISM coverage shown in pink. Minimum additional requested HiRISE stereo coverage shown by oranged dashed lines. Existing CTX and THEMIS data not shown, but covers the entire ellipse. For more details see the text.

Figure 2. Perspective view of part of a meander belt [2], showing trafficability of primary science targets. HiRISE orthophoto draped over our HiRISE stereeo DTM. No vertical exaggeration. View is to the SE and meander wavelength is \sim 0.3 km. This floodplain is <1.5 km from the center of the landing ellipse.



