

# J. Grant and S. Wilson

## Landing Site Imaging Update

MEPAG Meeting

February 25, 2015

Monrovia, CA

# Intro to Future Landing Sites on Mars:

- Multiple calls for future landing sites have resulted in 86 candidate sites (55 Future Sites, 2018, CDP) of which 31 are candidate sites for 2020 (multiple targets at many of these sites, 8 sites never requested images)
- Includes a wide range of future mission concepts/scenarios
  - Many candidate ellipses are 10 km X 15 km and many are relevant for 2020, but others specified by proposer
  - Many vetted at 2012 Future Landing Site Workshop at First 2020 landing Site workshop in May, 2014.
- Call for Critical Data Products (CDP) V, VI, and VII yielded additional candidates and valuable analyses of candidate sites and might be considered for 2020.
- Candidate Sites for all calls queued for imaging by MRO and other orbital assets
  - 2020 and ExoMars as MEP Must Haves, Wanna-Haves
  - Some sites/targets await CRISM cold cycles
  - Cadence is: Cold Cycle (rm216), 2020 2 and ExoMars 2 (rm217), 2020 3 and ExoMars 1 (218), 2020 3 and ExoMars 1 (219?), Cold Cycle, Wash, Repeat, Tumble Dry Gentle.
  - Example 2020 MEP MHs and WHs for cycle 218: 103258 McLaughlin (S2), 101606 Sabrina Valles (S2), 101708 NE Syrtis (S2), plus 101868 Kashira Crater alt., plus 4 additional Wanna-Haves
  - Targets entered in a given cycle relate to site priority, number of images needed, location on planet and relative to orbits, competition with other missions (ExoMars, InSight, Curiosity), competing science
  - A major exercise in spreadsheet management
- Mars Steering Committee co-chairs Grant and Golombek (only Grant appointed), not known when remaining members will be in place.

# Future Exploration/Landing Sites

As of February 18, 2015

	2020	Future Mars, MSR, 2018JR	MSL	Other*
# Images Acquired	99	222	262	711
% of Total Images Acquired in FE/LS	8%	17 %	20%	55%
# Remaining Suggested Images	29	10	29	331
% of Total Images Suggested in FE/LS	7%	3%	7%	83%

\*ExoMars, InSight, MPL, MER, Beagle, Viking, Phoenix, Public, RSLs, etc.

# Overview of Landing Site Imaging:

## MSL Landing Site in Gale Crater

- No Landing Site images of Gale since 7/2014 (but 5 images in other themes, like dunes)

## Landing Sites from Community Calls

- Includes Landing Sites from Future calls, CDP, 2018
- ~55 sites and ~130 targets; many imaged in stereo
- 222 images taken (~95% complete); 10 images remain, (4 S1 and 6 S2)
- 3 images since 7/2014

## 2020 Pre-Workshop and Workshop 1 Sites

- 31 unique sites
- 23 sites requested images, some sites didn't request (e.g., Hellas) and others don't need it (e.g., Melas, Gale, Holden, Eberswalde)
- 81 targets entered (many stereo)
- 128 total HiRISE images requested, 99 (77%) complete
- CRISM leads on CRISM cold cycle targets (9 in rm216, HiRISE usually rides along)
- 49 images since 7/2014 (completed 14 stereo pairs)

# MSL Campaign Target Statistics:

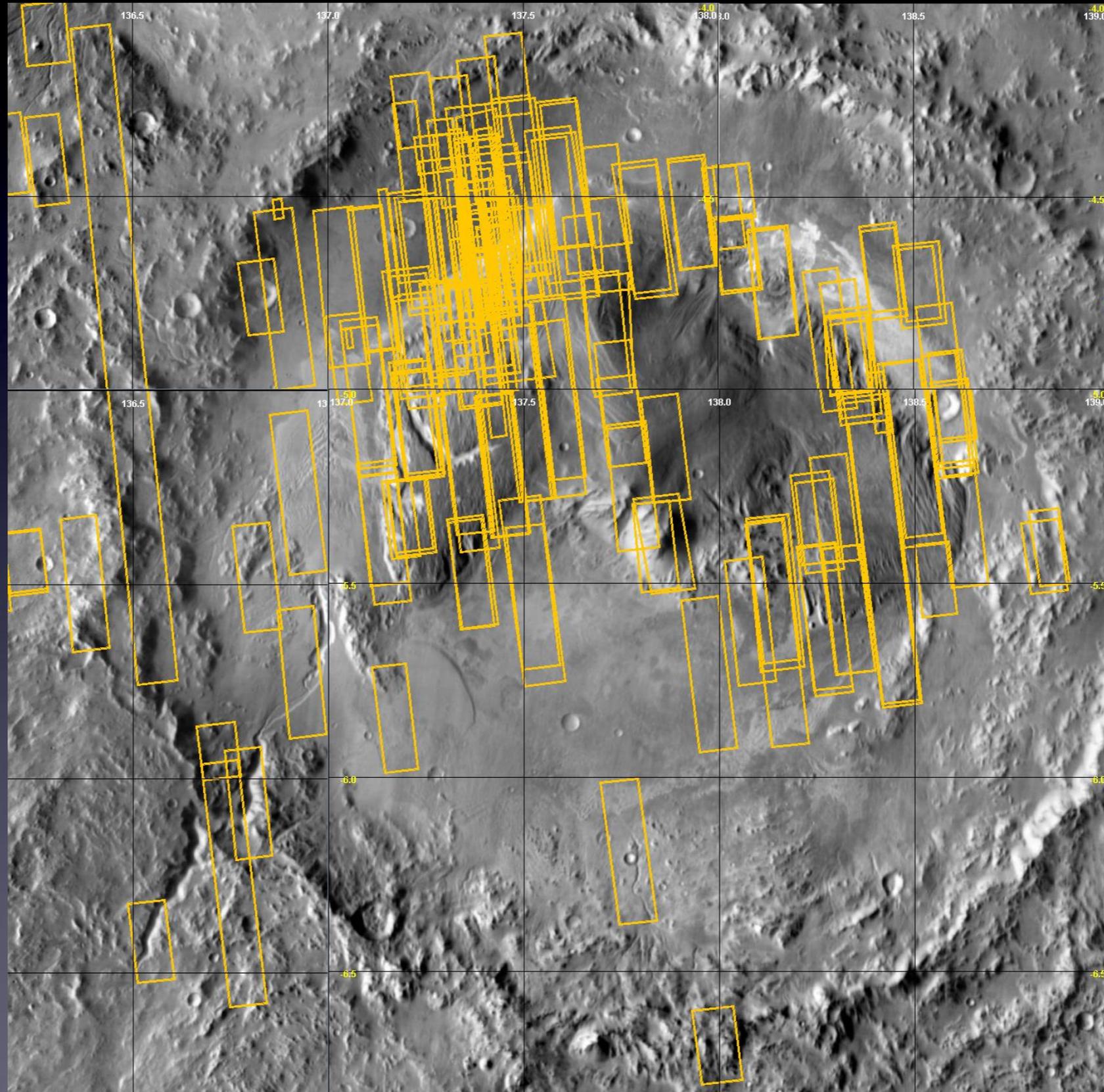
Does not include MSL targets outside of Landing Site targets  
As of February 18, 2015

	Number of Images	Percentage
<b>Released/Acquired</b>	<b>262</b>	<b>90% total</b>
<b>Planned</b>	<b>0</b>	<b>0%</b>
<b>Suggested</b>	<b>29</b>	<b>10% of total</b>
<b>Total</b>	<b>291</b>	

Remaining targets are acquired via normal process, except for Gale crater

# Example of HiRISE coverage in Gale

As of February, 2015



# Future Sites (CDP, 2018, etc)

Does not include 2020 candidate sites  
As of February 18, 2015

232 Images Requested in Total  
**>95% complete**

	Stereo 1	Stereo 2	Stereo 1 and Stereo 2
<b>Released/ Acquired</b>	<b>120</b> (+3 since 7/2014)	<b>102</b> (+0 since 7/2014)	<b>222</b>
<b>Suggested/ Remaining</b>	<b>4</b>	<b>6</b>	<b>10</b>
<b>Total Images</b>	<b>124</b>	<b>108</b>	<b>232</b>

# 2020 Mars Mission

# Current Draft 2020 Landing Site Selection Timeline

4-5 Workshops, 4-5 Years, Possible Selection L-2 or L-1 yr

Date	Title	Comments/Description	# of Sites
7/13	SDT report	<ul style="list-style-type: none"> <li>Preliminary engineering constraints</li> </ul>	
5/14	LSW 1	<ul style="list-style-type: none"> <li>Sites prioritized into thirds by science merit</li> <li>Top 3<sup>rd</sup> to be characterized for safety and TRN need by LSW 2</li> </ul>	27 (31)
7/14	Instrument selection	<ul style="list-style-type: none"> <li>PSG formed</li> </ul>	
8/15	LSW 2	<ul style="list-style-type: none"> <li>Identify 4-5 selectable sites                             <ul style="list-style-type: none"> <li>- Are there enough non-TRN sites of sufficient science merit?</li> <li>- If not, is TRN required? Define TRN attributes needed</li> </ul> </li> </ul>	~4-5 “selectable”  ~8 total
1/17	LSW 3	<ul style="list-style-type: none"> <li>~Middle of Phase C</li> </ul>	~4
6/18	LSW 4	<ul style="list-style-type: none"> <li>Final planned workshop</li> </ul>	~1
7/18	Site selection	<ul style="list-style-type: none"> <li>Decision dependent on number of high priority sites, clustering of sites, programmatic factors</li> </ul>	
7/19	LSW 5, if necessary	<ul style="list-style-type: none"> <li>Opportunity for LSW 5 if final site wasn't selected in 2018</li> </ul>	
7/20	Launch		

The Team (• = MPF, MER, and/or MSL experience)

**Principal Investigator:** James Bell (ASU) •

**U.S. Science Team Co-Investigators**

Justin N. Maki (JPL; Deputy P.I.) •

Tony Colaprete (NASA/Ames)

Ken Edgett (MSSS) •

\*\*Bethany Ehlmann (Caltech) •

Sarah Fagents (Univ. Hawaii)

John Grotzinger (Caltech) •

Alex Hayes (Cornell Univ.) •

Ken Herkenhoff (USGS/Flagstaff) •

\*\*Briony Horgan (Purdue Univ.)

Jeff Johnson (JHU/APL) •

Mark Lemmon (Texas A&M Univ.) •

Melissa Rice (Caltech) •

Mark Robinson (ASU)

Rob Sullivan (Cornell Univ.) •

Mike Wolff (Space Science Inst.) •

**Non-U.S. Science Team Co-Investigators**

Andrew Coates (Univ. College, London)

Ed Cloutis (Univ. Winnipeg)

Ralf Jaumann (German Aerospace Center, Berlin)

Kjartan Kinch (Univ. of Copenhagen) •

Morten Madsen (Univ. of Copenhagen) •

Gerhard Paar (Joanneum Research, Austria)

Frank Preusker (German Aerospace Ctr., Berlin)

\*\*co-chair, [Mastcam-Z Landing Site Working Group](#)

## 2020 Teams Getting Involved

### Mars 2020 Mastcam-Z team:

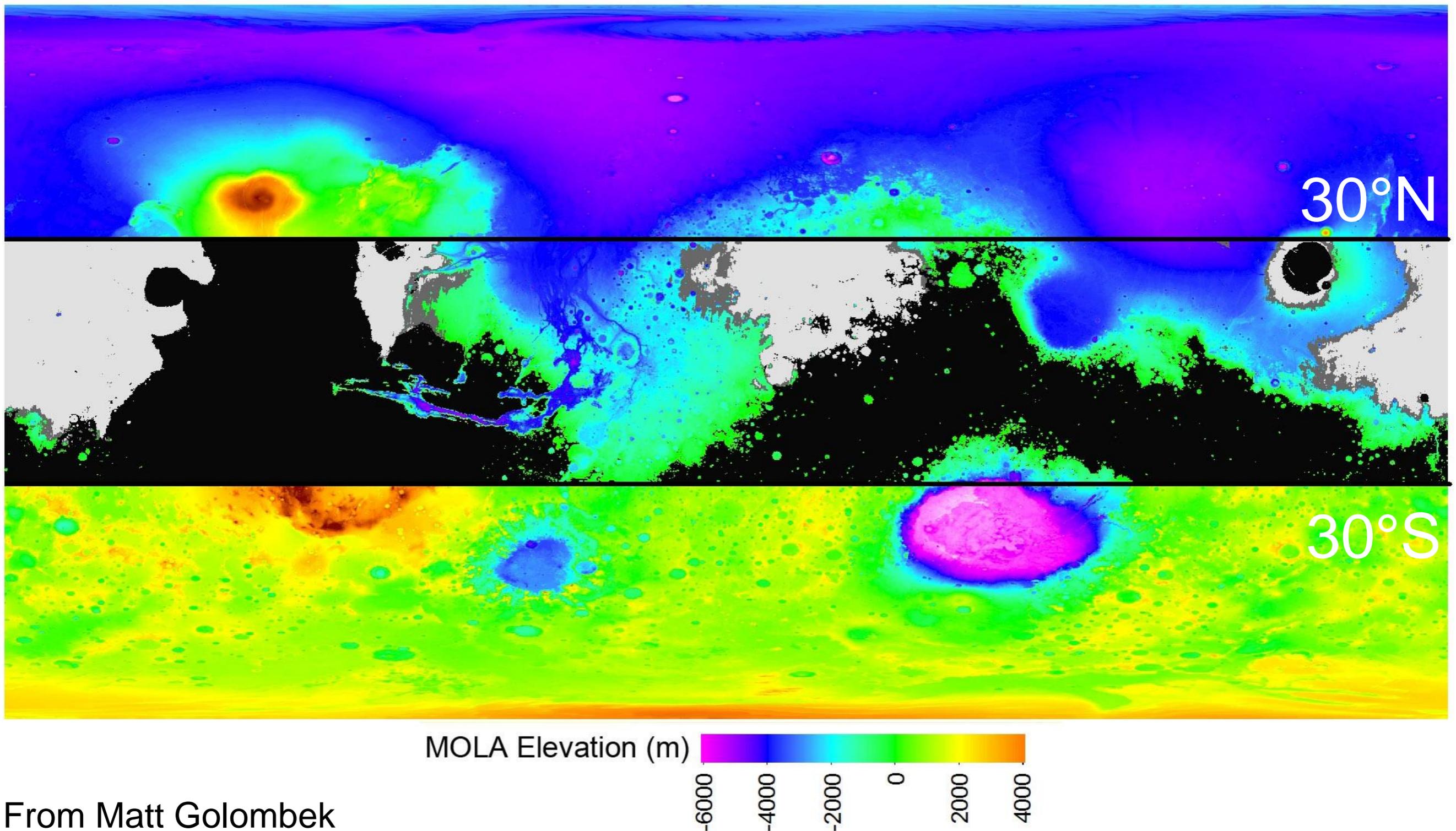
Colleagues with significant Mars surface operations experience...

Colleagues who will have significant roles in sample selection for Mars 2020...

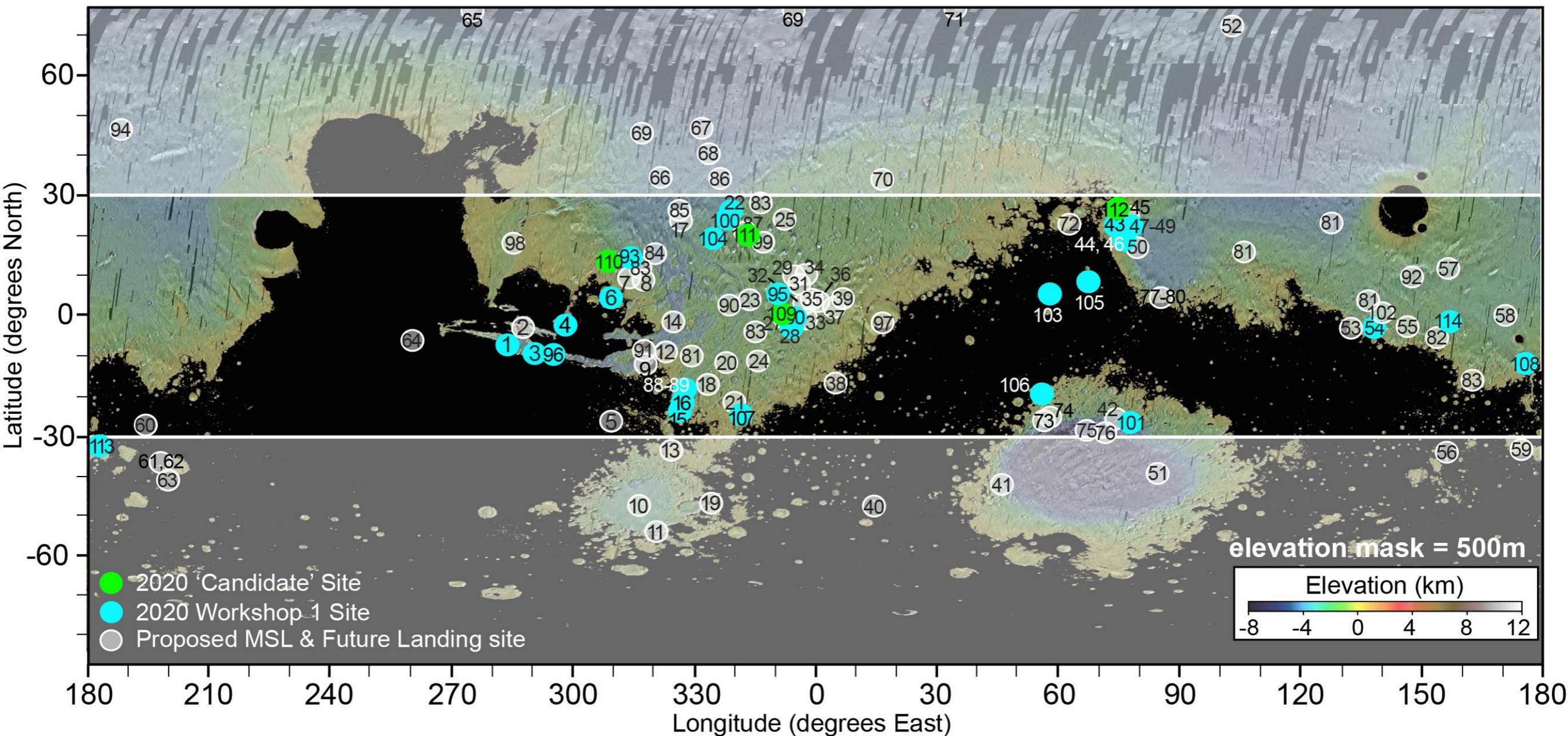
Colleagues who want to see the Mars 2020 site selection process benefit from "lessons learned" from the MER and MSL processes...

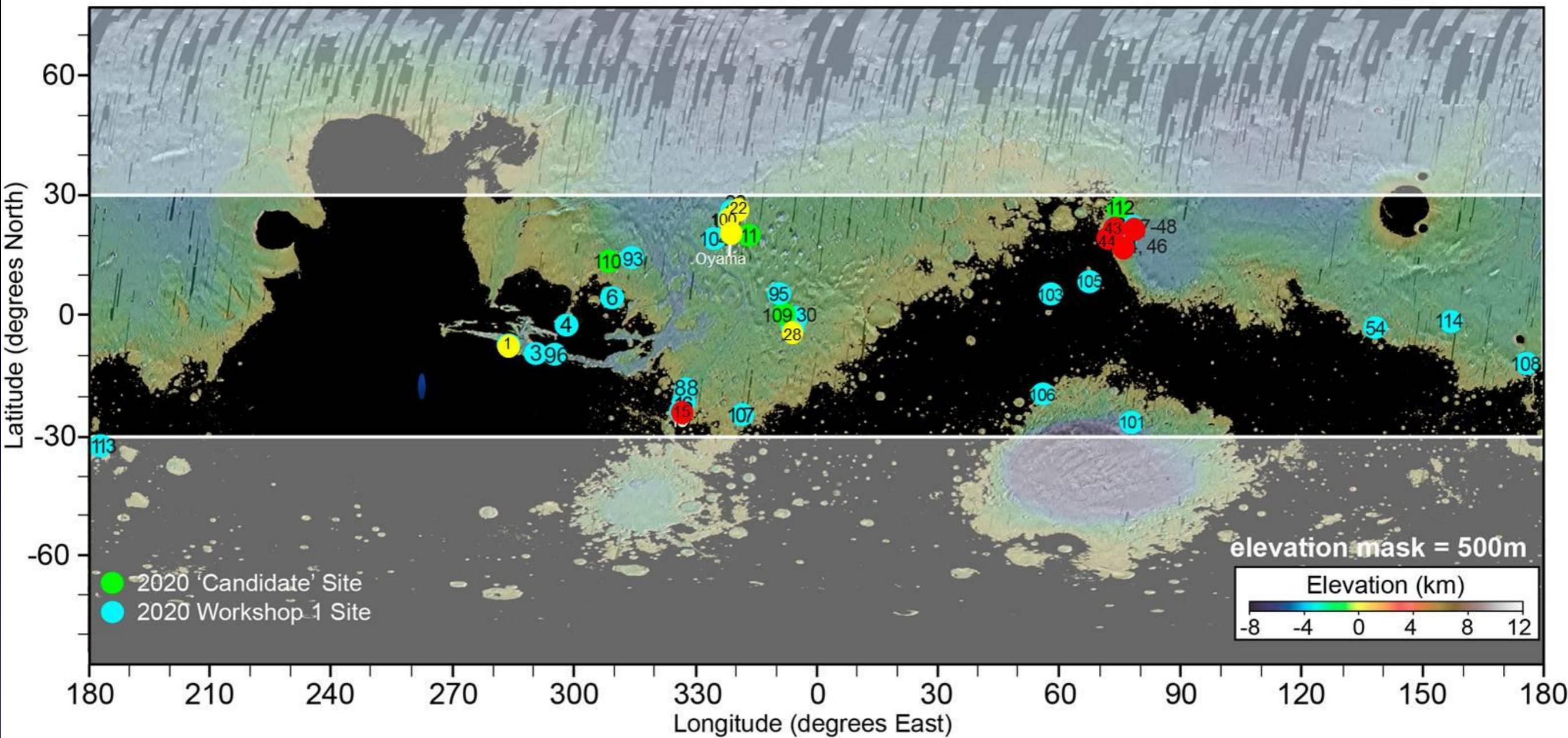
# Where 2020 Can Land: Elevation/Lat. Mask with Values of TES Thermal Inertia

- < 150 = dark gray (Christensen et al. 2001)
- < 100 = light gray



# 2020 sites vs. MSL and other proposed FLS





**MARS 2020 WORKSHOP SITES (listed in order of presentation schedule, BLUE DOTS)**

- |   |  |
|---|--|
| Dot 100: McLaughlin Crater (Michalski, J. et al.)   | Dot 16: Eberswalde Crater (Irwin, R. P., III)  |
| Dot 103: Leighton Crater (Michalski, J. et al.)   | Dot 46: Jezero Crater (Gupta, S., et al. and Ehlmann, B. L., et al.)                                 |
| Dot 22: Mawrth Vallis (Loizeau, D. et al.)  | Dot 88: Ladon Valles (Weitz, C., et al.)   |
| Dot 104: Oxia Planum (Thollot, P., et al.)  | Dot 93: Sabrina Vallis (Platz, T., et al.)   |
| Dot 43: Nili Fossae Trough (Mustard, J. F., et al.)                                       | Dot 113: Eridania Basin (Noe Dobrea, E. Z., et al.)  |
| Dot 48: Nili Fossae Carbonates (Ehlmann, B., et al.)                                      | Dot 107: Kashira crater (Edgett et al.) (2020 Candidate Site from M. R. Salvatore)                   |
| Dot 44: NE Syrtis Major (Mustard, J. F., et al.)  | Dot 28: Eastern Margaritifer Terra (Christensen, P., et al.)   |
| Dot 105: Nili Patera (Skok, J. R., et al.) (2020 Candidate Site from Skok, J. R., et al.) | Dot 101: Hadriacus Palus (Skinner, J. A., et al.,)   |
| Dot 106: Hellas (Noe Dobrea, E. Z., et al.)   | Dot 95: Firsoff Crater (Pondrelli, M., et al.) (2020 Candidate Site from Pondrelli et al.)           |
| Dot 3: Melas Chasma (Miyamoto et al.) (2020 Candidate Site from S. M. R. Turner, et al.)  | Dot 108: Gusev Crater (Ruff, S. W. et al.; Longo, A.; Rice, J.) (2020 Cand. Site from Cabrol et al.) |
| Dot 4: Juventae Chasma (Miyamoto et al.)  | Dot 54: Gale Crater (Grant, J.)  |
| Dot 1: Melas Basin (Williams, R. M. E., et al.)   | Dot 30: Meridiani Planum (M. Golombek)   |
| Dot 96: Coprates Chasma (Quantin, C., et al.)   | Dot 15: Holden Crater (Irwin, R.)  |
| Dot 6: Hypanis delta in Xanthe Terra (Gupta, S., et al.)                                  | Dot 114: Aeolis (Yakovlev, V)  |

**MARS 2020 CANDIDATE SITES (GREEN DOTS)**

- Dot 109: Farthest West Meridiani (Edgett et al.)
- Dot 110: Vistula Valles/Chryse (Edgett et al.)
- Dot 111: Intercrater West Arabia (Edgett et al.)
- Dot 112: Nilosyrtis crater (Saper, L)

# 2020 Sites After First Workshop:

<http://marsnext.jpl.nasa.gov/workshops/index.cfm>

Candidate Landing Site	Weighted Average	Need for Additional Imaging by	Is Site Likely Land On or Go To?	Is Range Trigger Likely Needed for Access?	Does Range Trigger Reduce the Need for TRN?	Does Access Likely Require TRN?	If Go To, Would TRN Likely Make Land On?
NE Syrtis	2.78	High	Mostly Land On	Yes	Probably	Probably	No
Nili Fossae Trough	2.59	Low	Mostly Go To	No	Yes	Yes	No
Nili Fossae Carbonates	2.56	Low	Land On	Yes	No	Yes	No
Jezero Crater Delta	2.33	Low	Partially Go To	No	No	Yes, to avoid rocks	No
Holden Crater	2.24	Low	Go To	No	No	No	Possibly
McLaughlin Crater, 21.85N, 337.73E, -5.05km	2.24	Medium	Mostly Land On	No	Probably	?	?
Southwest Melas Basin	2.22	Low	Land On	Yes	No	Probably Not	No
Mawrth Vallis, MSL Site	2.16	Low	Land On	No	No	No	No
East Margaritifer Chloride	2.13	Low	Land On	No	No	Yes	No
Oyama Crater, clay layers	2.13	Medium	Land On	No	No	No	No
Eberswalde Delta	1.98	Low	Go To	No	No	No	No
Ladon Valles	1.97	Medium	Land On	No	No	No	Yes
Gusev Crater	1.91	Low	Land On	No	No	No	No
Oxia Planum, clay layers, Mawrth like	1.80	High	Land On	No	Probably	Probably	No
Nili Patera Hydrothermal	1.84	Medium	Mostly Go To	?	?	?	?
Hadriacus Palus	1.71	High	Land On	No	Yes	Not with RT Ellipse	No
Hypanis Delta	1.65	Medium/High	Land On and Go To	No	Yes	?	?
Kashira Crater	1.66	High	Go To	Maybe	?	?	Probably
Circum-Hellas Hydrothermal	1.55	Medium	Go To	No	?	?	?
Coprates Chasma	1.52	Medium	Mostly Go To	No	Probably	Probably	No
Sabrina Vallis	1.42	Medium	Partially Go To	No	Yes	No	No
Gale Crater	1.36	Low	Go To	No	No	No	No
Firsoff Crater	1.32	High	Land On	No	No	No	No
Valles Marineris - Melas Chasma Floor, RSL	1.32	Medium	Go To	No	?	?	?
Valles Marineris - <b>Capri</b> Chasma, RSL	1.28	Medium	Go To	No	?	?	?
Valles Marineris - Juventae Chasma, RSL	1.22	Medium	Go To	No	?	?	?
Meridiani Planum	1.10	Low	Land On	No	No	No	No

# We Need TRN to Access Many of the Top Sites



- Of the top nine sites identified at the 1<sup>st</sup> Landing Site Workshop, only two can be reached definitively without TRN
  - Two non-TRN sites: Holden and Mawrth
    - Both were unselected MSL finalist sites
    - Holden site could utilize TRN to convert to a land-on site
  - Two other sites lack sufficient terrain data to make an assessment (yet)

Rank	Candidate Landing Site	Elevation (km, MOLA)	Land On or Go To?	TRN Required?
1	NE Syrtis	-2.15	Mostly Land On	Yes
2	Nili Fossae Trough	-0.61	Mostly Go To	Maybe
3	Nili Fossae Carbonates	-1.50	Land On	Yes
4	Jezero Crater Delta	-2.50	Partially Go To	Yes
5	Holden Crater	-2.14	Go to without TRN; Land on with TRN	No for Go To; Yes for Land On
6	McLaughlin Crater	-5.05	Mostly Land On	Don't Know Yet
7	Southwest Melas Basin	-1.85	Land On	Don't Know Yet
8	Mawrth Vallis, MSL Site	-2.29	Land On	No
9	East Margaritifer Chloride	-1.25	Land On	Yes

***Our choices may be limited without TRN***

# 2020 Candidate Sites Submitted Pre-workshop 1

As of February 18, 2015

9 sites added December 2013

28 targets, 52 Images Requested in Total  
>92% complete

	Stereo 1	Stereo 2	Stereo 1 and 2
<b>Released/ Acquired</b>	26	22	48 (+2 since 7/14)
<b>Suggested/ Remaining</b>	0	4	4 (7% remaining)
<b>Total</b>	26	26	52

# Breakdown of Pre-Workshop 2020 “Candidate Sites”

As of February 18, 2015

	LOCATION	# TARGETS	REQUESTED STEREO PAIRS	COMPLETE IMAGES	REQUESTED IMAGES	REMAINING IMAGES
1	Gusev crater	5	5	9	10	1 (S2)
2	East Melas	2	1 (+1 S2)	2	3	1 (S2)
3	Farthest W. Meridiani	3	3	6	6	COMPLETE
4	Vistula Valles/Chryse	3	3	5	6	1 (S2)
5	Intercrater W. Arabia	3	3	6	6	COMPLETE
6	Firsoff crater	3	2	5	5	COMPLETE
7	Kashira crater	4	3	6	7	1 (S2)
8	Nili Patera	3	2 (+1 S2)	5	5	COMPLETE
9	Nilosytris crater	2	2	4	4	COMPLETE
	<b>TOTAL</b>	<b>28</b>	<b>25</b>	<b>48</b>	<b>52</b>	<b>4 stereo 2s</b>

# 2020 Candidate Submitted Post Workshop 1

As of February 18, 2015

17 sites\* added to list for imaging July 2014

53 targets 76 Images Requested in Total

67% Complete

	Stereo 1	Stereo 2	Stereo 1 and 2
Released/ Acquired	37	14	51
Suggested/ Remaining	13	12	25 (33% remaining)
Total	50	26	76

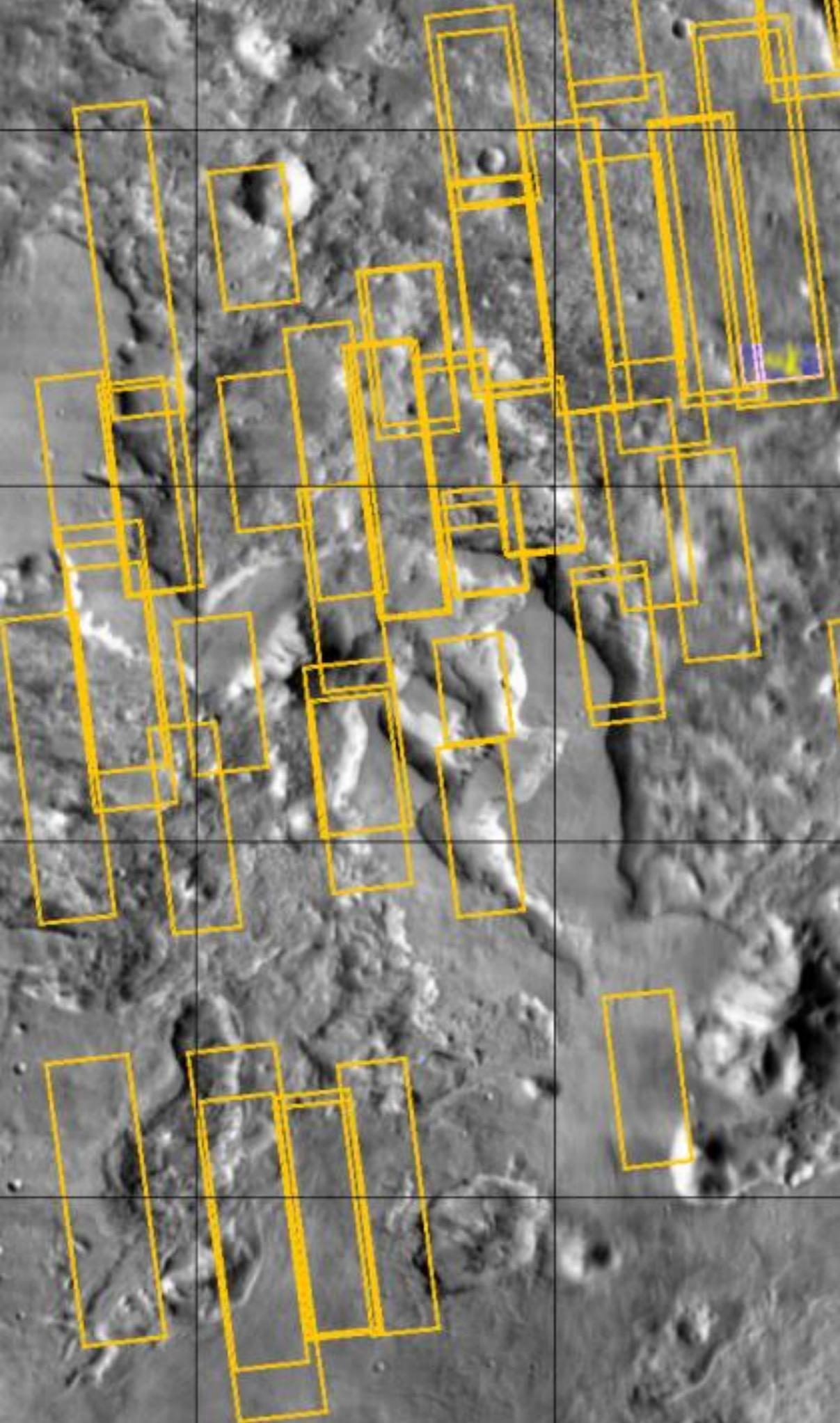
\*8 proposed sites did not need or have not requested images

# Status for 17 2020 Sites Requesting Images

As of February 18, 2015

	LOCATION	# TARGETS	REQUESTED STEREO PAIRS	COMPLETE IMAGES	REQUESTED IMAGES	REMAINING IMAGES
1	Hadriacus Palus	3	2	4	5	1
2	Oyama crater	6	1 (+1 stereo 2)	5	7	2
3	Firsoff crater	2	1	1	3	2
4	Jezero crater	4	4	7	8	1
5	Sabrina Vallis	3	2 (+1 stereo 2)	3	5	2
6	Nili Carbonate	1	0	1	1	COMPLETE
7	Kashira crater	3	2	3	5	2
8	NE Syrtis	9	3 (+ 1 stereo 2)	6	12	6
9	Hypanis	2	2	1	4	3
10	Melas Chasma	2	0	0	2	2
11	Capri	1	0	1	1	COMPLETE
12	Coprates Chasma	2	0	2	2	COMPLETE
13	Oxia Planum	6	0	4	6	2
14	Gusev	1	0	1	1	COMPLETE
15	Nili Fossae Trough	4	2	6	6	COMPLETE
16	McLaughlin crater	3	3	4	6	2
17	Ladon Vallis	1	1	2	2	COMPLETE
	TOTAL	53	23 (+ 3 stereo 2s)	51	76	25

	Rank after W1	Site #	Name	Lat (°N)	Lon (°E)	Approx. Elev. (km)	Total # Regional Images	# Stereo Pairs	Images acquired/ images requested before/after 2020 W1	ROI submitted
Mars 2020 Workshop 1 Sites (blue dots)	1	44	NE Syrtis Major	17.8	77.1	-2	49	17	6/12	Mustard
	2	43	Nili Fossae trough	21	74.5	0.6	22	7	6/6	Mustard
	3	48	Nili Fossae carbonates	21.9	78.9	-1.5	26	8	1/1	N/A
	4	46	Jezero crater	18.5	77.4	-2	>45	12	7/8	Goudge
	5	15	Holden crater	-26.4	325.1	-2.2	40	>10	0/0	Irwin
	6	100	McLaughlin crater	21.9	337.8	-5	25	4	4/6	Michalski
	7	1	Melas basin	-9.8	283.4	-1.85	>20	>8	0/0	Williams
	8	22	Mawrth (MSL site)	24	341	-3	>25	>10	0/0	Loizeau
	9	28	E. Margaritifer	-5.6	353.8	-1.25	11	4	0/0	Christensen
	10	22	Oyama crater	23.4	340.2	-3.89	12	2	5/7	Loizeau
	11	16	Eberswalde crater	-23	327	-1.4	>40	>12	0/0	Rice
	12	88	Ladon Valles	-20.5	329.9	-2.05	26	11	2/2	Weitz
	13	108	Gusev crater	-14.4	175.6	-1.94	>55	>8	10/11	Ruff
	14	104	Oxia Planum	17.8	336	-3	16	4	4/6	Loizeau
	15	105	Nili Patera	9	67.43	0.2	>50	>10	5/5	
	16	101	Hadriacus Palus	-26.9	78	-2.66	22	6	4/5	Skinner
	17	6	Hypanis delta	11.8	314.6	-2.7	21	6	1/4	
	18	107	Kashira crater	-27.2	341.4	-0.38	19	6	9/12	
	19	106	Hellas	-26	56	~1	13	4	0/0	
	20	96	Coprates Chasma	-12.6	296.1	-5	14	4	2/2	
	21	93	Sabrina Vallis	11.7	313.1	-2.5	12	5	3/5	Platz
	22	54	Gale crater	-4.6	137.4	-4.5	>150	>20	0/0	Curiosity
	23	95	Firsoff crater	3	350.6	-2.74	28	10	6/8	Pondrelli
	24	3	Melas Chasma	-12.2	290	-5	24	>3	0/2	
	25	96	Capri Chasma	-15.4	308	-4.45	10	1	1/1	
	26	4	Juventae Chasma	-4.5	298.5	-3.1	31	>5	0/0	
	27	30	Meridiani Planum	-3.3	354.6	-1.6	>50	>10	0/0	
n/a	103	Leighton crater	3	57	0.42	13	2	0/0		
n/a	113	Eridania basin	?	?	?	n/a	n/a	0/0		
n/a	114	Aeolis	-1.5	157.1	-2.8	n/a	n/a	0/0		
Pre-workshop 1 Sites (green dots)	n/a	109	Farthest W. Meridiani	-0.6	351.7	-1.96	> 15	4	6/6	
	n/a	110	Vistula Valles/Chryse	14.7	309.5	-2.6	7	3	5/6	
		111	Intercrater West	19.9	342.9	-2.03	19	6	6/6	



# 1. NE Syrtis

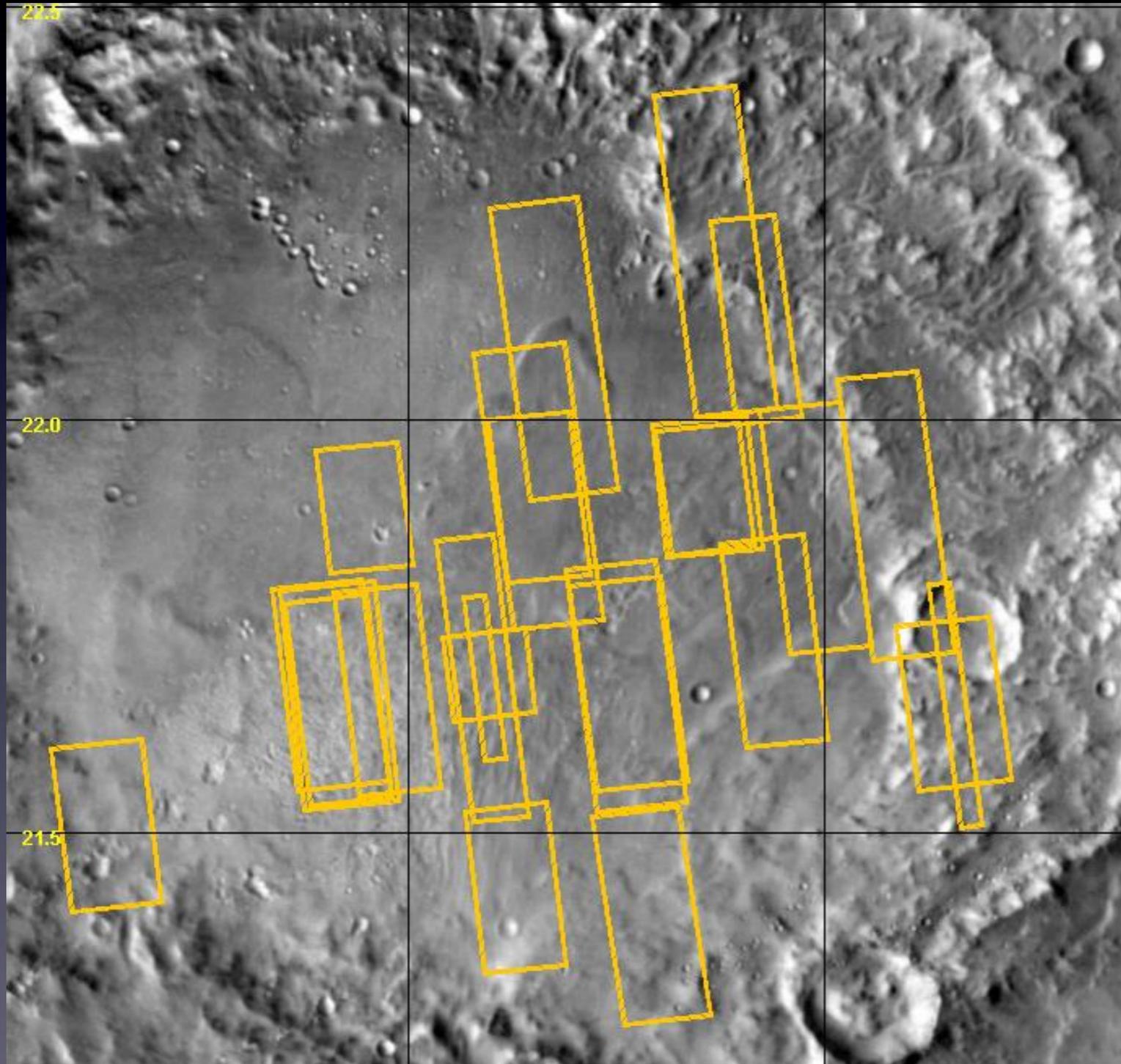
- Added 9 targets after 2020 W1
- Requested:
  - 12 H
  - 3 CRISM
- Complete:
  - 6 H
  - 0 CRISM
- Region: 49 H (17 SP)

# 4. Jezero Crater



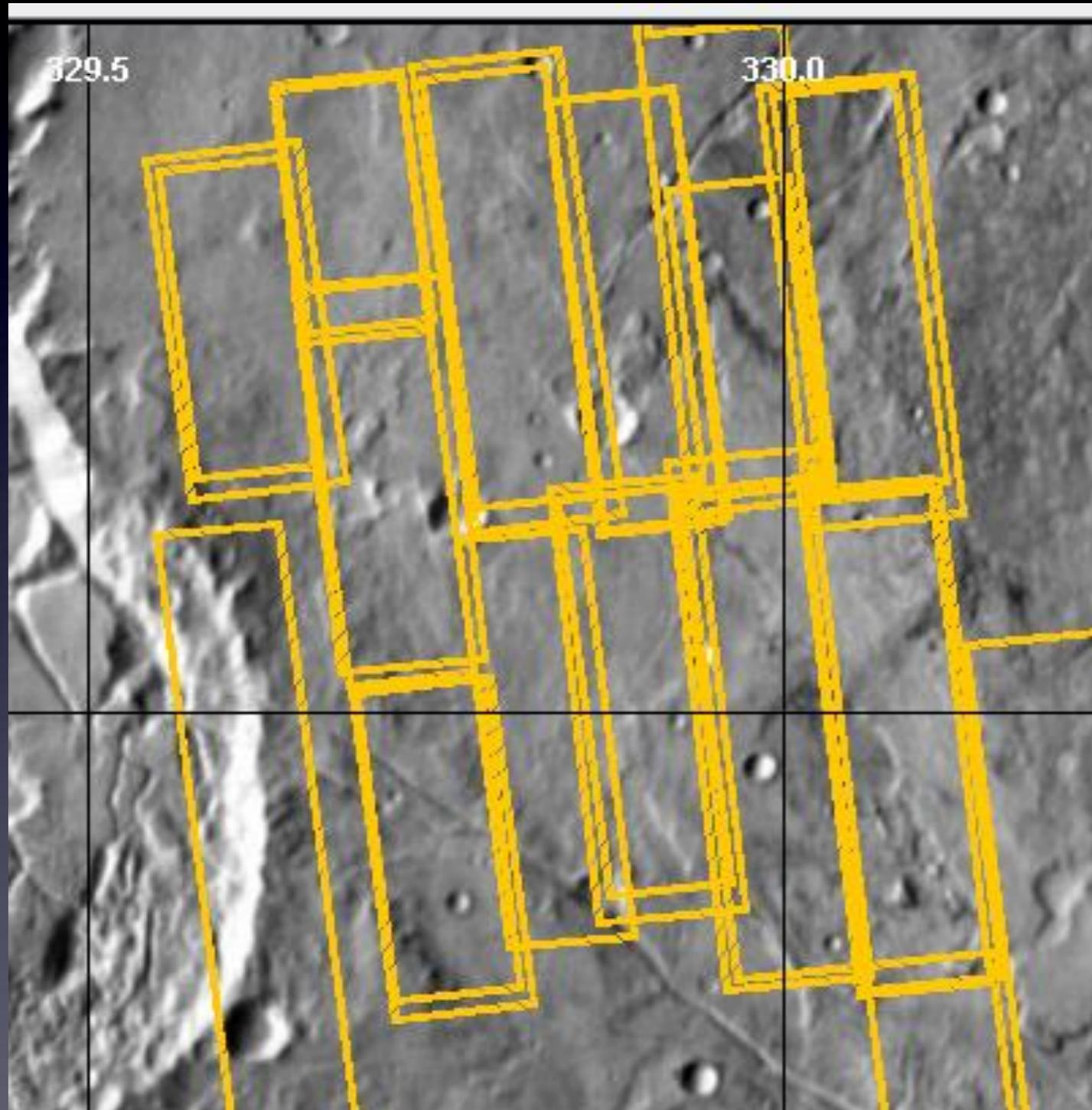
- Added 4 targets after 2020 W1
- Requested:
  - 8 H (4 SP)
  - 2 CRISM
- Complete:
  - 7 H (3 SP)
  - 2 CRISM
- Region: 45+H (12+ SP)

# 6. McLaughlin Crater



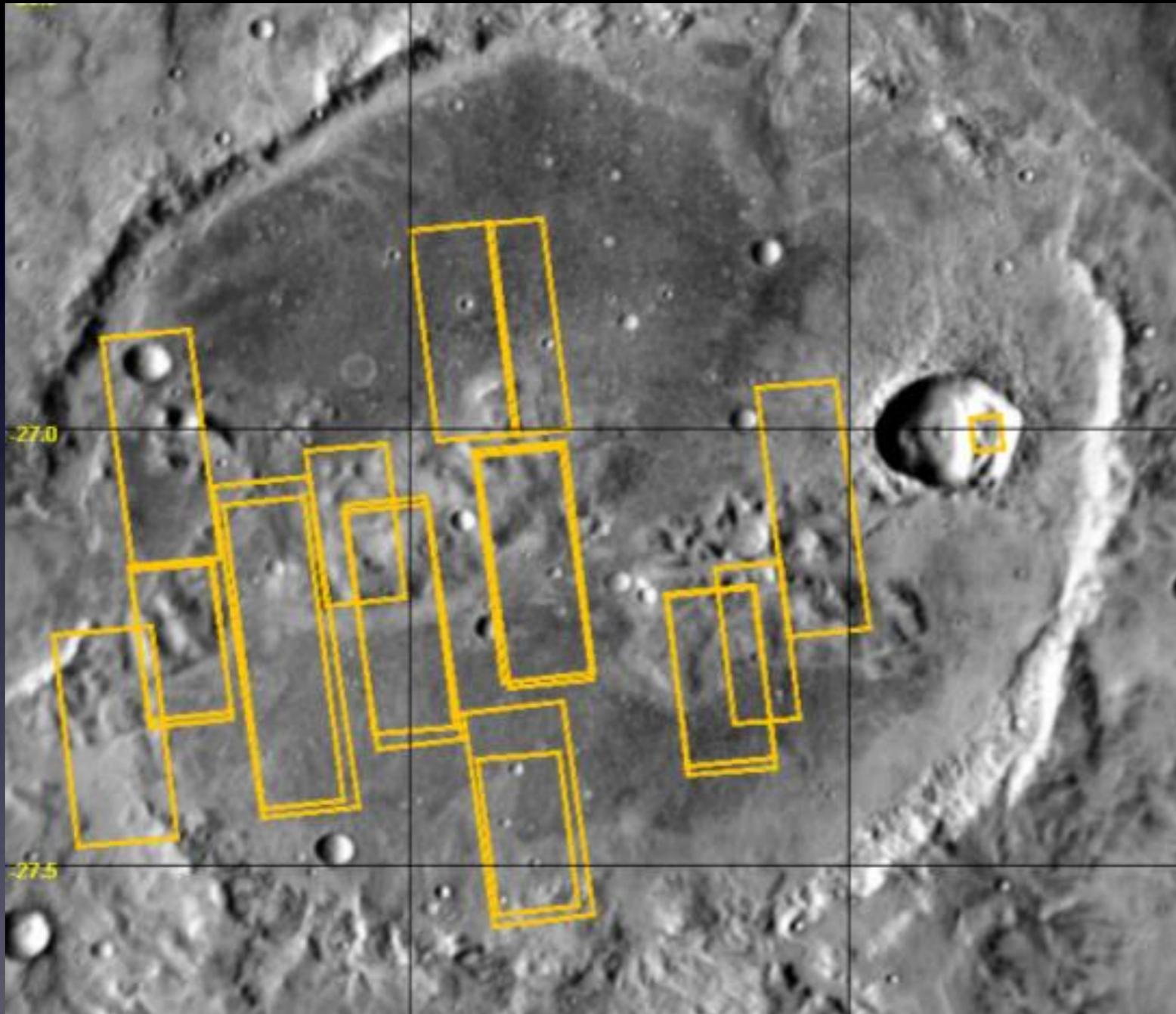
- Added 3 targets after 2020 W1
- Requested:
  - 6 H (3 SP)
  - 2 CRISM
- Complete:
  - 4 H (1 SP)
  - 1 CRISM
- Region: 25 H (4 SP)

# 12. Ladon



- Added 1 target after 2020 W1
- Requested:
  - 2 H (1 SP)
  - 0 CRISM
- Complete:
  - 2 H (1 SP)
  - 0 CRISM
- Region: 26 H (11 SP)

# 18. Kashira Crater



- Added 7 targets before and after 2020 W1
- Requested:
  - 12 H (5 SP)
  - 5 CRISM
- Complete:
  - 9 H (3 SP)
  - 3 CRISM
- Region: 19 H (6 SP)

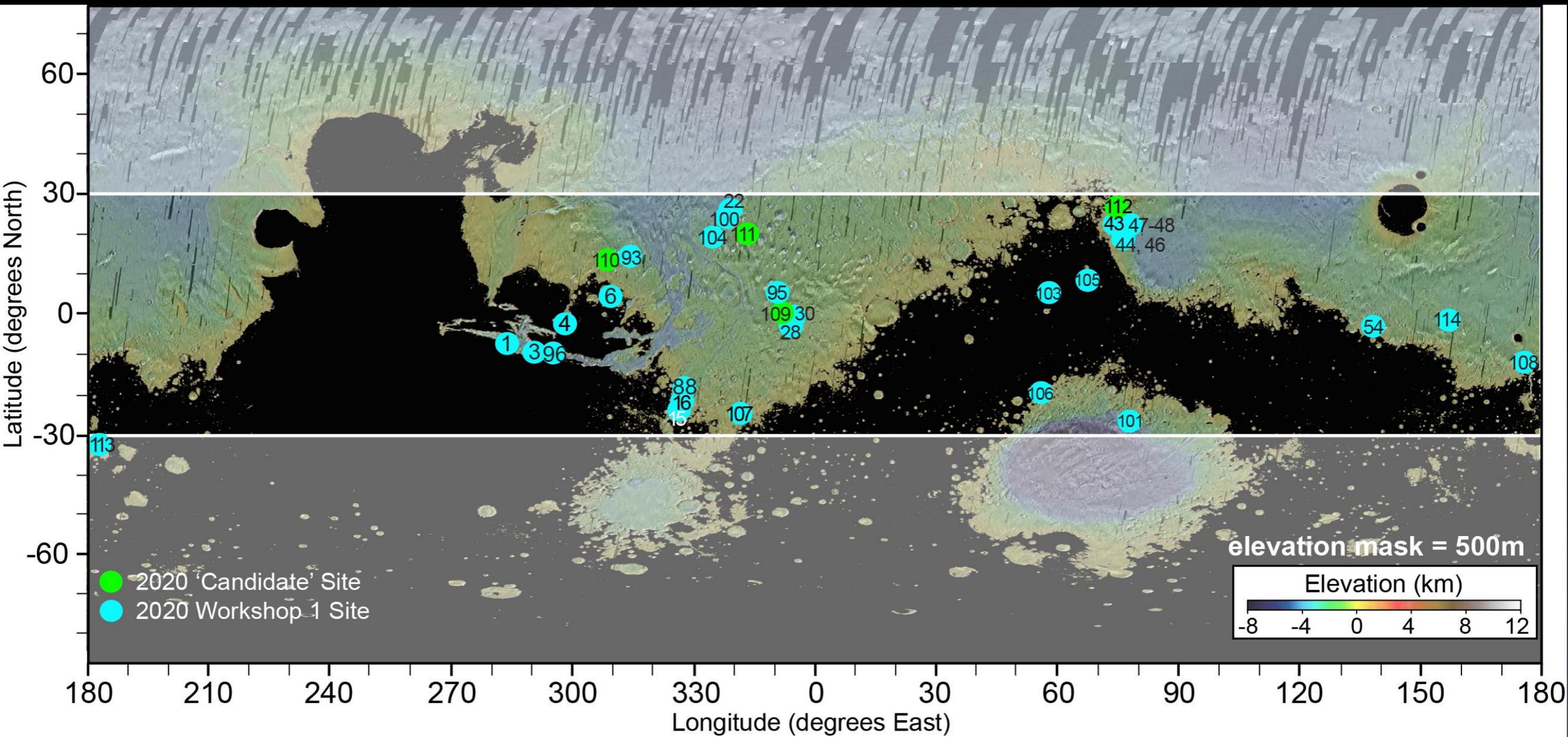
# Summary of Results to Date (February 2015)

- Total of >583 HiRISE images acquired to date for MSL/Future/2018/2020
- 262 HiRISE images acquired of MSL sites
  - Spread around ~65 candidate sites over ~6 years
  - 0 in Gale since LTM (in FE/LS theme)
- Total of 86 Future/2018/2020 candidate sites proposed
- Only 78 Requested Images (some already can be certified)
- Range of missions and ellipses
  - Some have appeared before (MER and MSL)
  - Lots of spreadsheets to keep track of...
- Most sites have multiple, prioritized targets
- 321 HiRISE images acquired of Future/2018/2020
  - 52 since LTM, mostly 2020 targets remain
  - 99 2020 HiRISE images taken so far
  - 39 Future/2018/2020 HiRISE images left to acquire (includes 2<sup>nd</sup> half stereo)
- CRISM Lead during “cold cycles” – Stats through rm216
  - Total of 160 non-MSL targets acquired cold out of 169 attempted
  - 111 acquired out of 113 attempted future/2018/MSR targets
  - 12 acquired out of 13 attempted ExoMars targets
  - 37 acquired out of 13 attempted 2020 targets
  - 24 2020 targets left to acquire; 6 Future/2018/MSR targets left
  - HiRISE typically rides along on these

Backup

# 2020 “Candidate” & “Post-Workshop 1” Sites

As of July, 2014



● Candidate Sites (pre-workshop 1)

● Workshop 1 Site