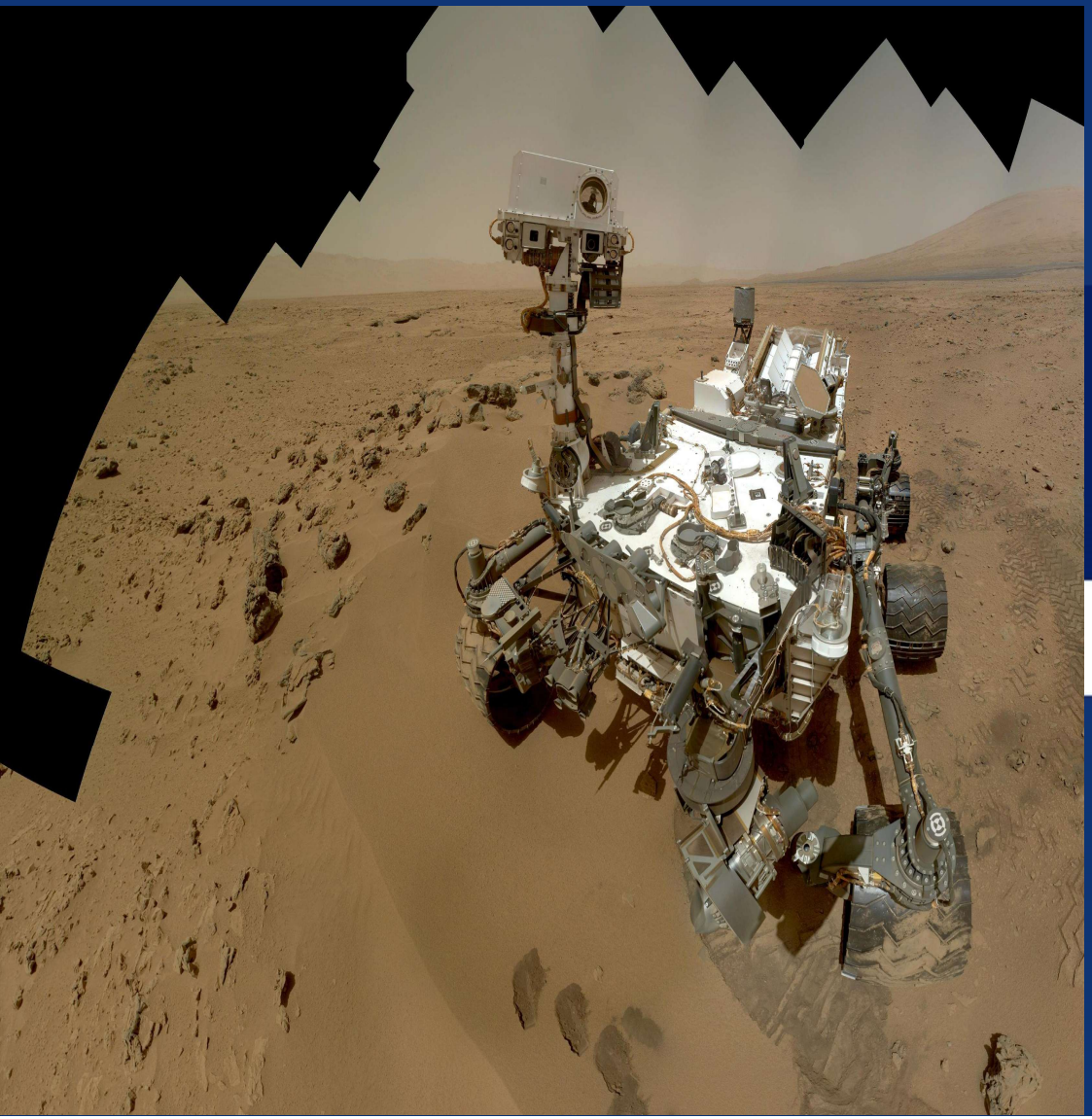


Systèmes Automatiques & Robotiques

Opérations Instrument CHEMCAM à bord du Rover Martien CURIOSITY

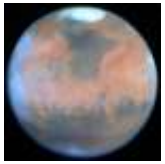
Vivian Lafaille – CNES (DNO/SC/EO)

SOMMAIRE

- GENERALITES SUR L'EXPLORATION MARTIENNE
- LA MISSION MSL
- L'INSTRUMENT CHEMCAM
- LE SYSTEME & LES OPERATIONS
- CONCLUSION / QUESTIONS
- *QUELQUES RESULTATS …*

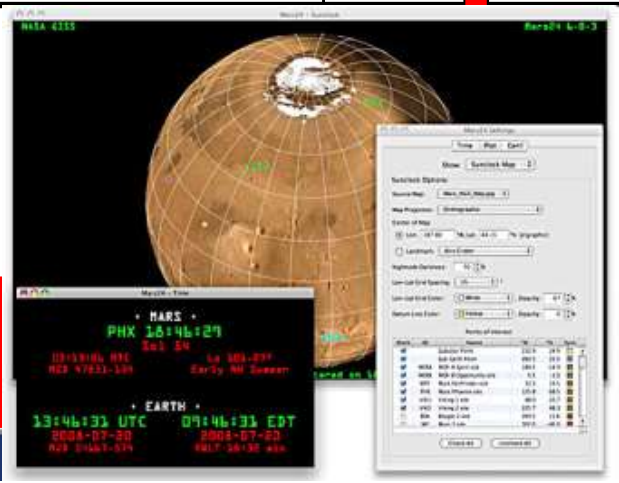
GENERALITES

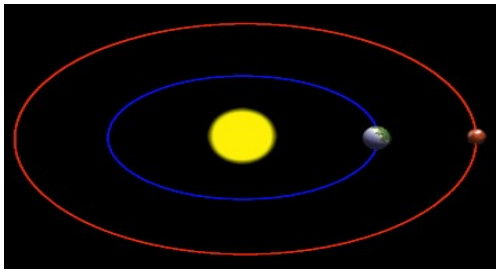
Mars 4iéme planète la plus éloignée du Soleil : Mercure, Vénus, Terre, Mars

		Equatorial Diameter (km)	Orbit	Mean Sun Distance (km)	Mean Solar Day	Tropical Revolution Period
TERRE		12 756,28	e=0,01671 i~23°	149,60 millions	24,0000 h 24h 00 min 00 s	365,2422 j 365 j 5 h 48 min 46,08 s
MARS		6 794 (0,5326 x Earth)	e=0,09340 i~25°	227,94 millions	24,65973 h 24 h 39 min 35 s	686,973 days 668,5921 sols

- **Temps Martien (LMST) pilote des opérations**
  - Datation à la surface de Mars en heure locale solaire de 24h
  - Heures, minutes secondes sont 2.7% plus longues que sur la Terre

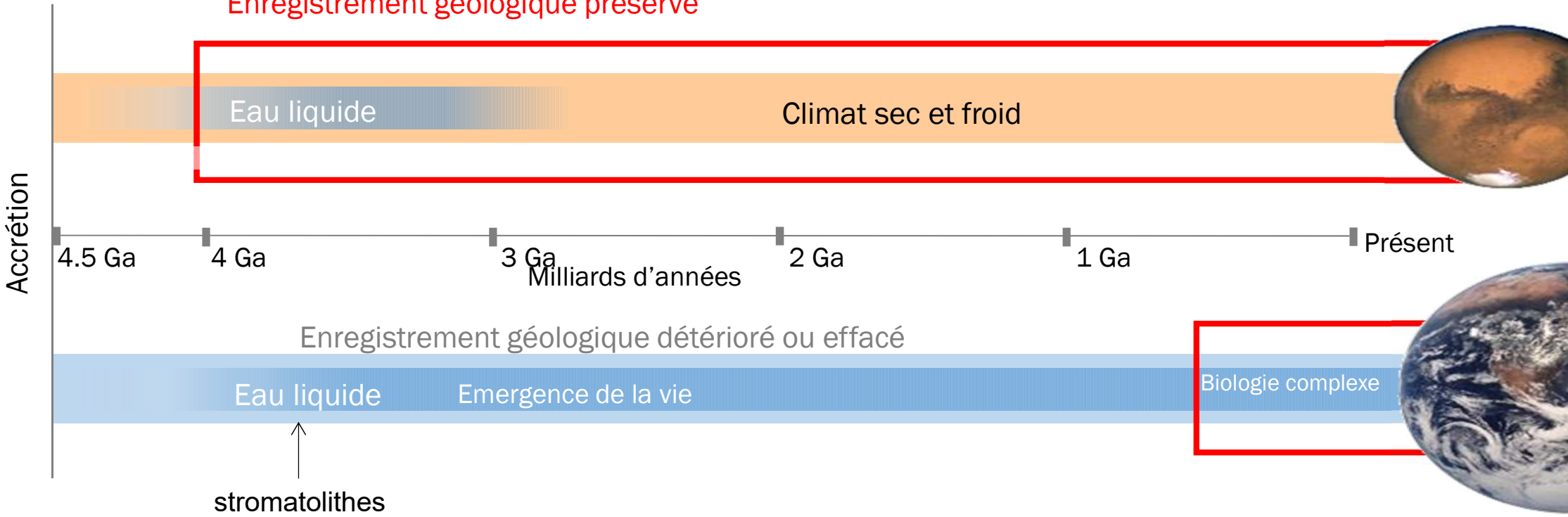
SOL (Mars) = DAY (Earth) + (~ 40 mn)
36 SOLs (Mars) = 36* (DAY (Earth) + 40 mn)
= 37 DAYs (Earth) SOLIDAY





TEMPS PROPAGATION
3mn 7sec
20mn 57sec

GENERALITES : Pourquoi étudier Mars ?



- Etudier l'habitabilité de Mars
- Comprendre la formation des premiers continents

Exploration de Mars

2018

2020

SuperCam

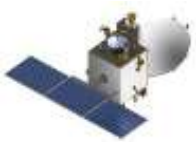
Partenariat

- **CNES**
- **CNRS**
- **Universités**

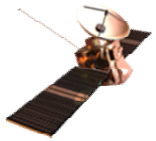
Mars Odyssey

MRO

Mangalayaan

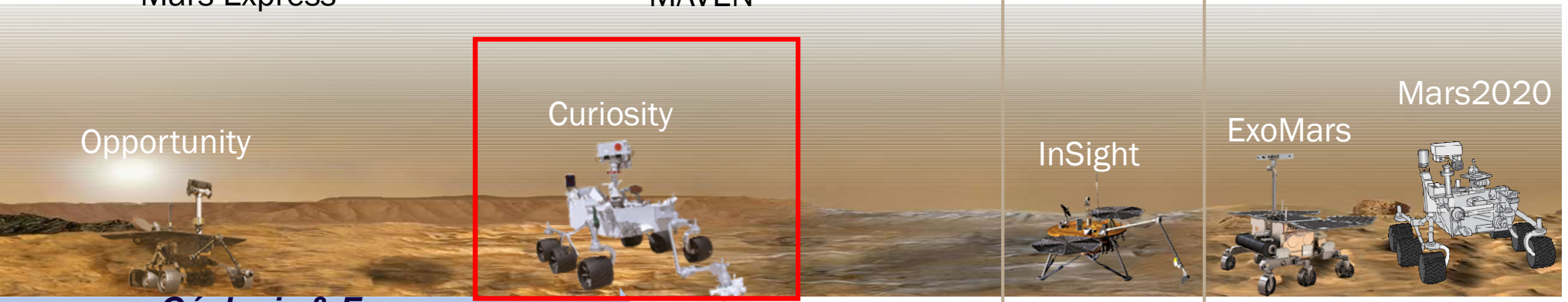


TGO



Mars Express

MAVEN



Géologie & Eau

Environnement & Habitabilité

Traces de vie

Préparation du retour d'échantillons et des missions habitées

MARS SCIENCE LABORATORY (MSL)

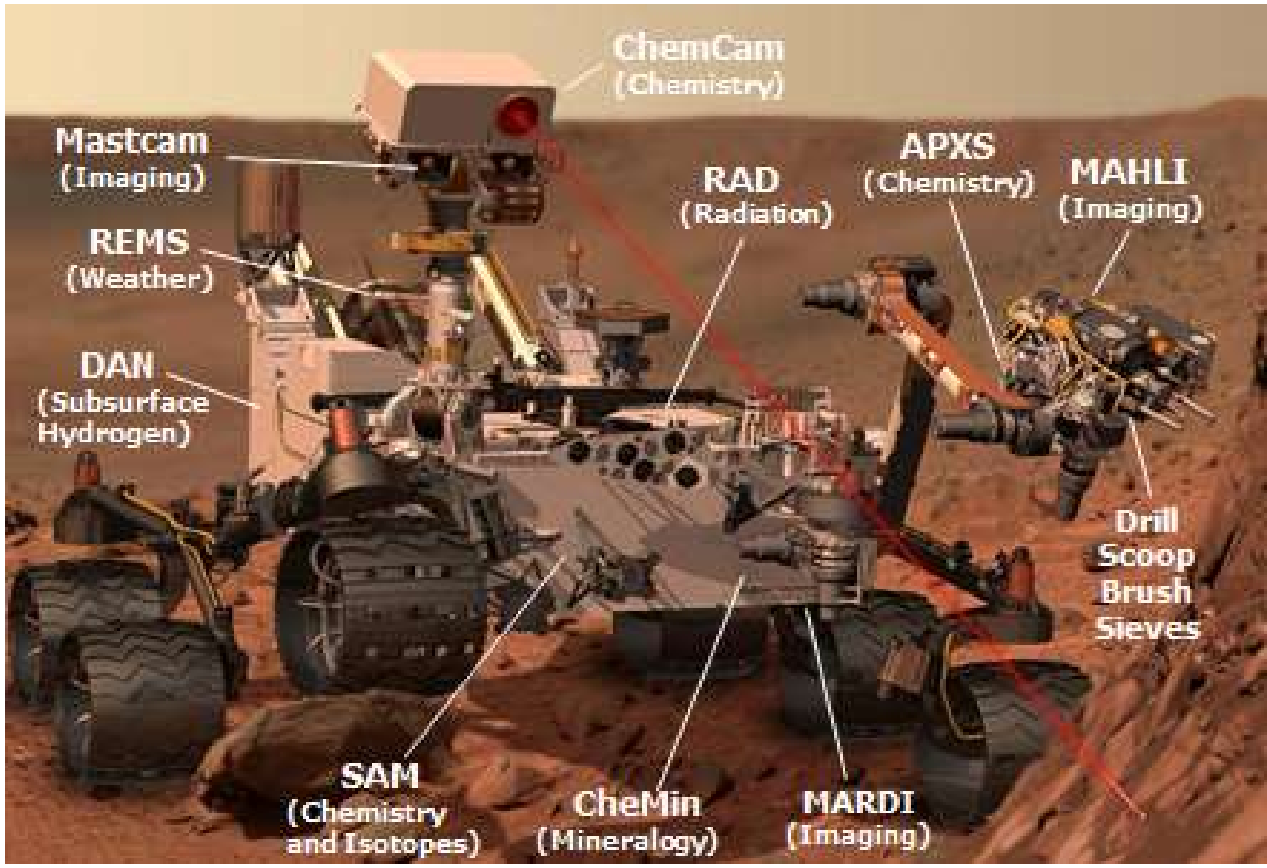
CURIOSITY :
- **900 kg (Small car size)**
- **2.5 kw/h**

Science
- **75 kg**
- **10 instruments**

MARS SCIENCE LABORATORY (MSL)

- **Mastcam** : 34 & 100 mm cameras
- **ChemCam** : Chemistry camera :
  - Laser-Induced Breakdown Spectroscopy (LIBS)
  - Remote Micro-Imager (RMI)
- **APXS** : Alpha Particle X-ray Spectrum.
- **MAHLI** : Mars Hand Lens Imager
- **ChemMin** : Chemistry & Mineralogy
  - X-Ray Diffraction
  - X-Ray Fluorescence
- **SAM** : Sample Analysis at Mars
  - Quadripole Mass Spectrometer (QMS)
  - Gas Chromatograph (GC)
  - Tunable Laser Spectrometer (TLS).
- **RAD** : Radiation Assessment Detector
- **REMS** : Rover Environmental Monitoring Station
- **DAN** : Dynamic Albedo of Neutrons
- **MARDI** : Mars Descent Imager

4 Science Themes : **Organic geochemistry & Bio signatures, Inorganic geochemistry & Mineralogy, Geology, Atmosphere & Environment**



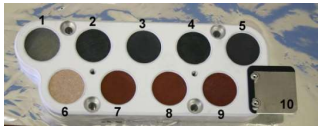
cnes

ChemCam : Chemistry camera

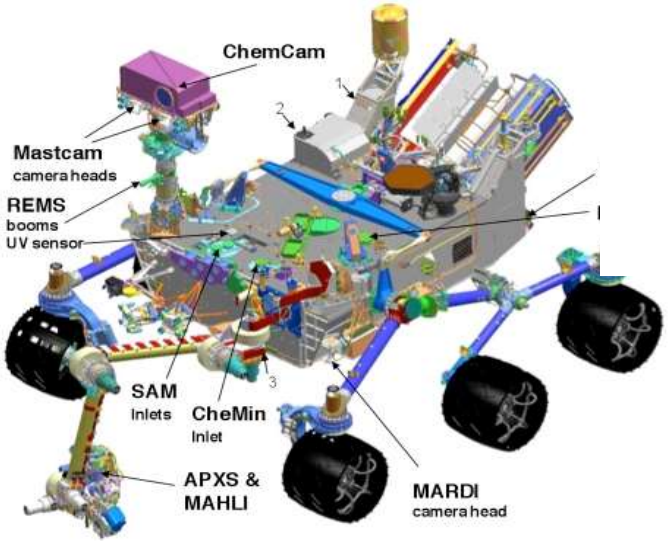
- Laser-Induced Breakdown Spectrometer (LIBS)
- Remote Micro-Imager (RMI)

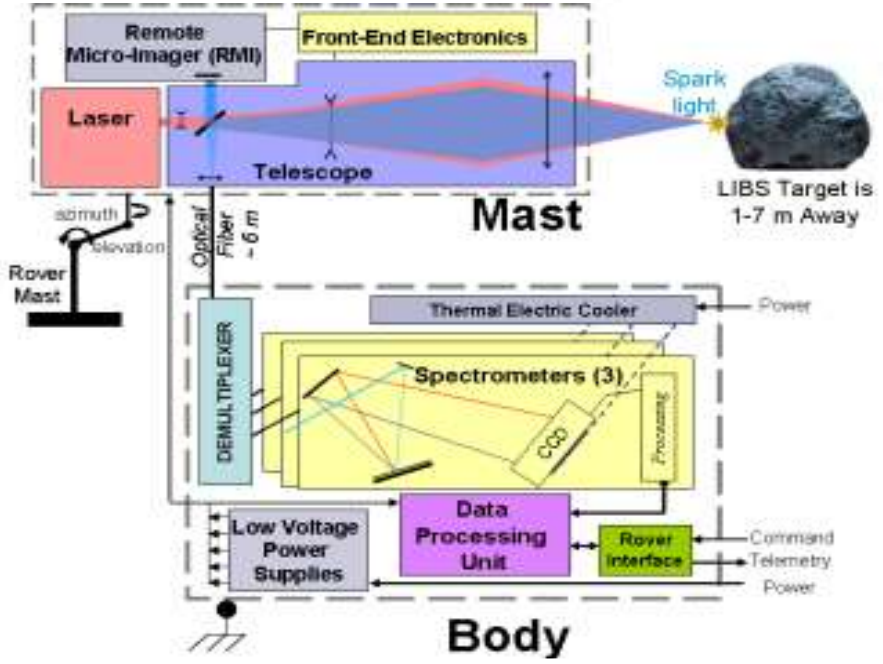
Mast Unit

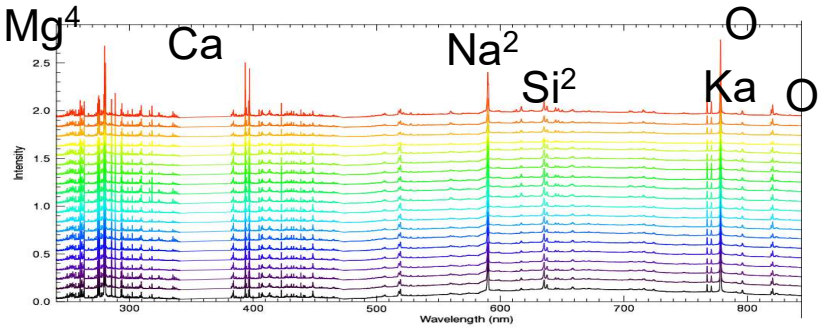
Body Unit



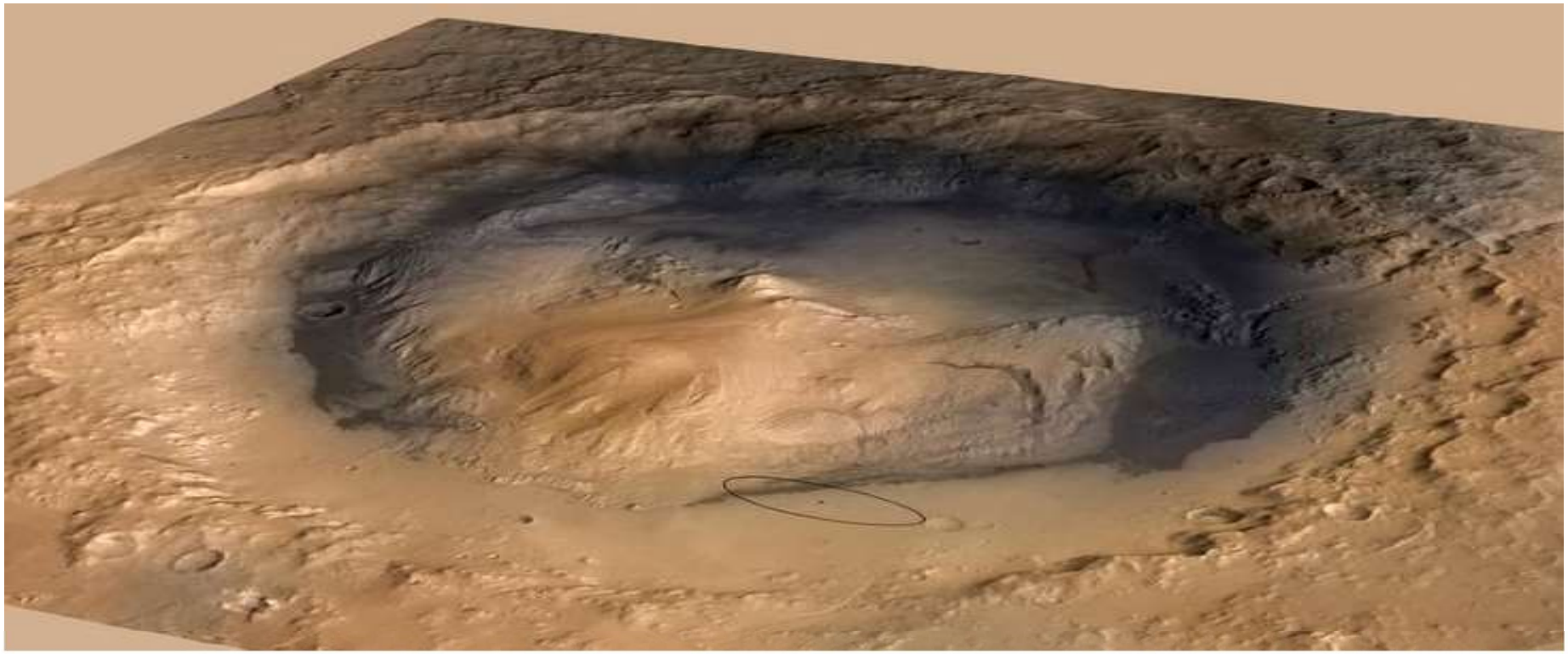
Calibration Targets





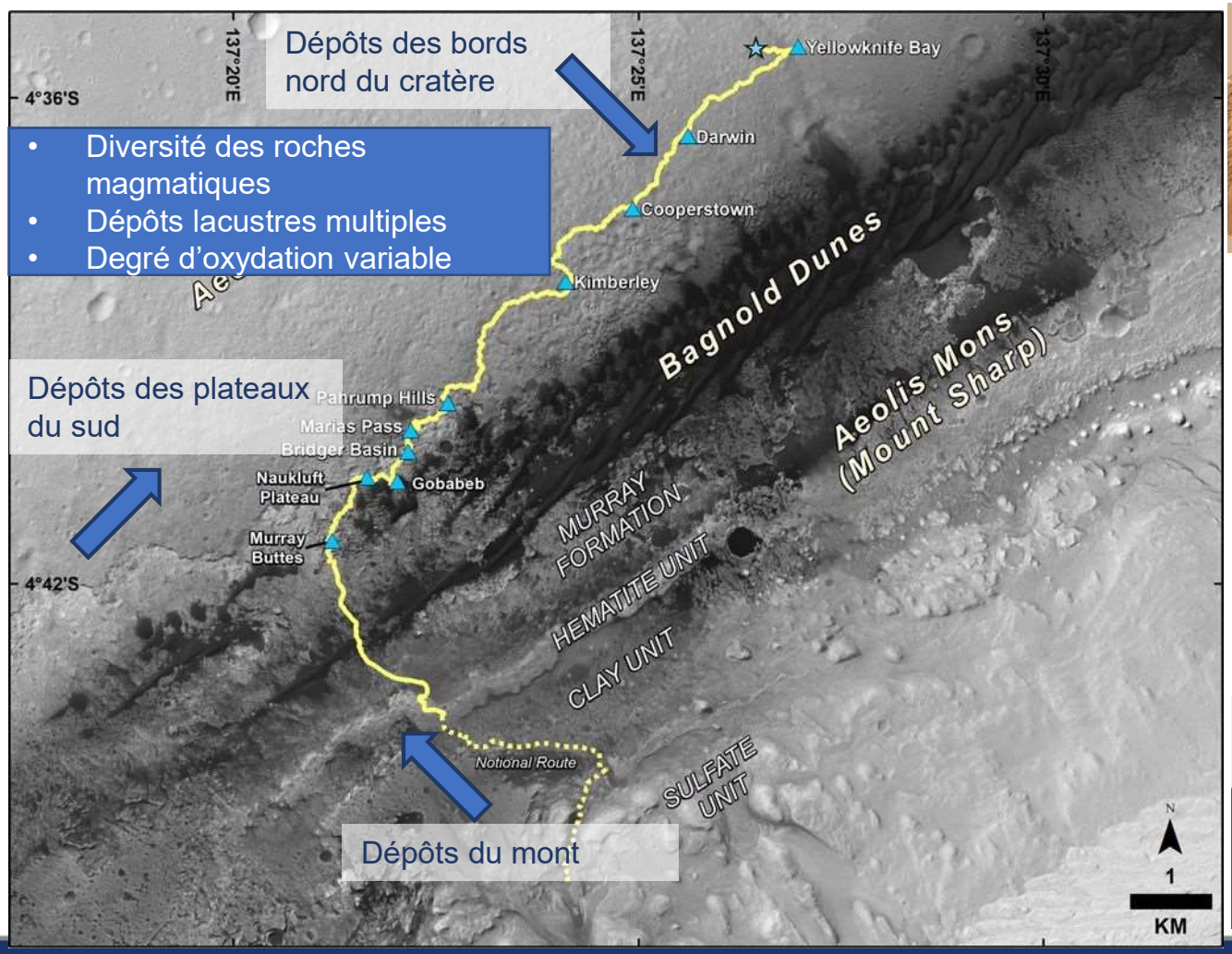


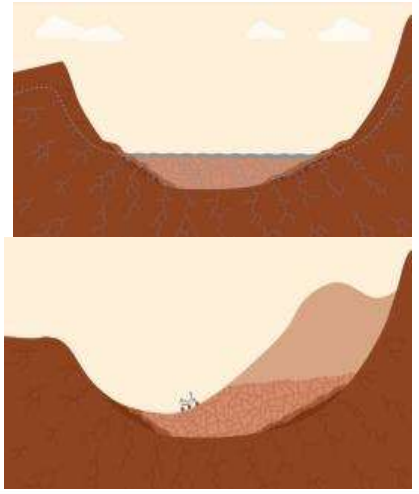
LE SITE D'ATTERRISSAGE : Gale Crater



150-km Gale Crater contains a 5-km high mound of stratified rock. Strata in the lower section of the mound vary in mineralogy and texture, suggesting that they may have recorded environmental changes over time.

Le Parcours : ~17 kms en 5 ans



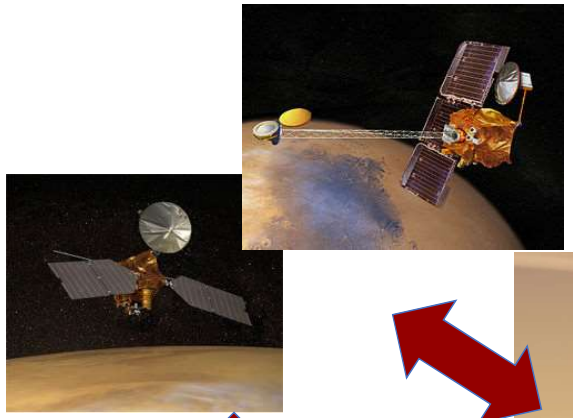


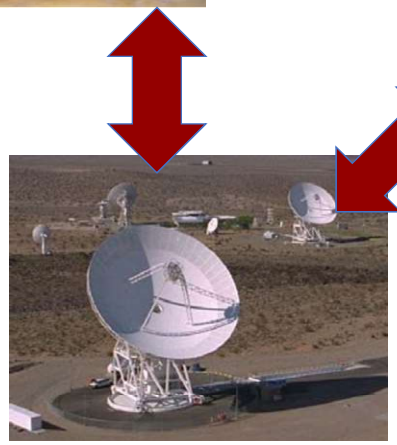
LE SYSTEME

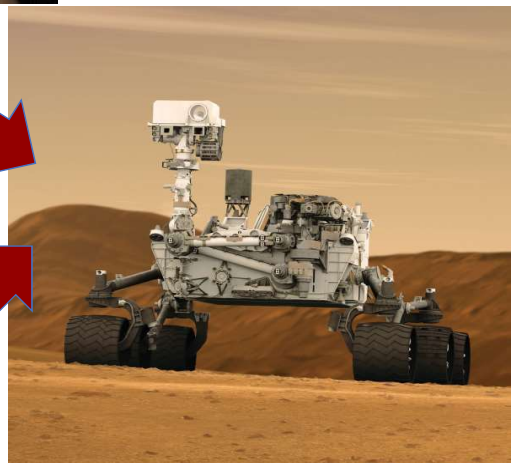
Operations
À distance

Operations MSL
Coordination

Operations Locales
(90 sols)







Opérations selon 2 approches:

- Stratégique

- P.S.G.
- Long Term Planning

- Tactique

- S.O.W.G.
- Plan d'activités par Sol

LES OPERATIONS TACTIQUES

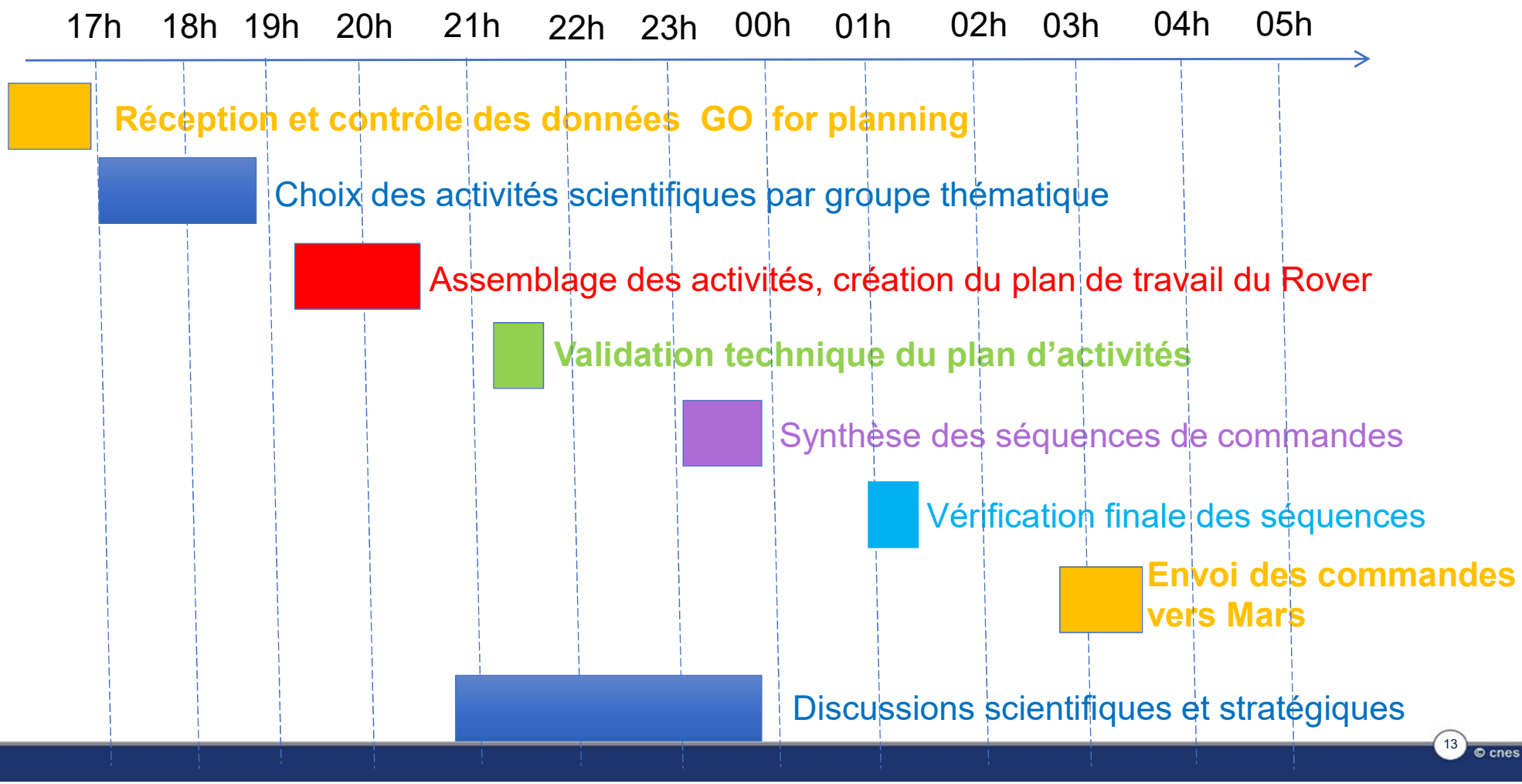
Pilotées par le temps martien

Activités Sol N | **Activités Sol N+1**

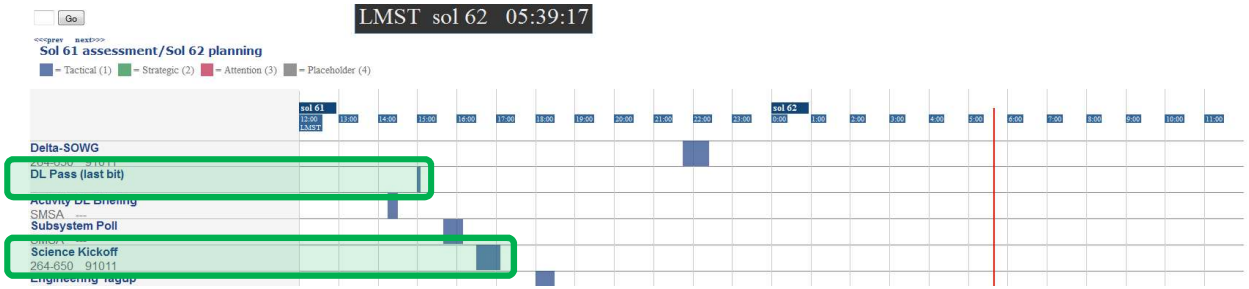
Engineering:
- Sol N Validation
- Sol N +1 Programmation

Science :
- Sol N Validation
- Plan Sol N+1
- Pre-Plan Sol N+2

Opérations quotidiennes (JPL w.h.)



Bilan activité Sol n



Covered period: from SOL-1436M02:57:52 to SOL-1436M23:36:45

- CCAM final state: **HEALTHY**, OFF
- Sun Safety assessment: **TRUE** (ACM-5304), final motor position: **4010** (CCAM-6009)
- CCAM PRTs remained within AFT domain.
- RSM ACM states: **Nominal**

Sequences execution table

SeqID	Activity Name	Starting Date (MSLICE)	*Starting Date (Actual)*	Duration (MSLICE)	Duration (SeqGen)	*Duration (Actual)*	Warning Low	Warning Hi	Failed S-CMD	THRM-2593 (°C)
Science Block #1										
ccam15002	ChemCam_TEC_Cooling	SOL-01436M11:03:50	*SOL-1436M11:03:50*	00:30:00	00:00:01	*00:00:00*	0	0	0	-24.8
ccam15700	ChemCam_Instrument_On	SOL-01436M11:33:02	*SOL-1436M11:33:01*	00:08:00	00:06:43	*00:06:09*	4	0	0	-21.9
ccam01436	ChemCam_RLR_Line_1x10_Diag_Conda_ccam	SOL-01436M11:40:49	*SOL-1436M11:39:01*	00:20:58	00:22:31	*00:21:13*	0	0	0	-21.6
ccam02436	ChemCam_RLR_Line_1x10_Vert_Savungo	SOL-01436M12:01:13	*SOL-1436M11:59:41*	00:24:14	00:25:57	*00:23:18*	0	0	0	-19.7
ccam15003	ChemCam_Instrument_SunSafe_Off	SOL-01436M12:24:48	*SOL-1436M12:22:22*	00:06:51	00:06:51	*00:06:48*	0	0	0	-15.9
TOTAL (TEC not accounted)				01:00:03	01:02:02	*00:57:30*				
ccam15000	CleanUp	SOL-01436M13:03:55	*SOL-1436M13:03:55*	00:08:00		*00:00:02*	1	0	1	-10.8

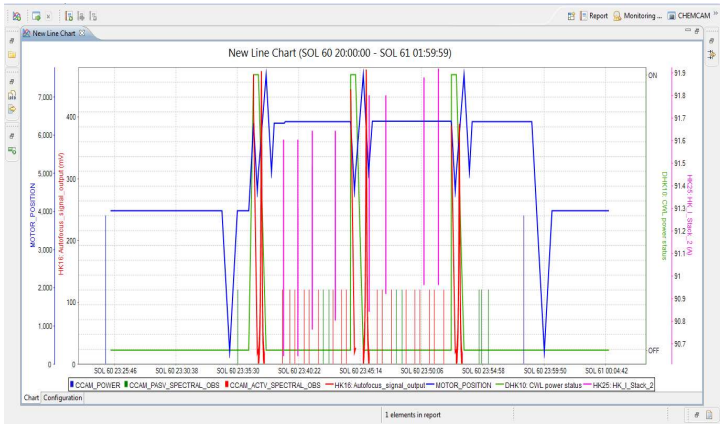
Generated by ARC 2.6

No AEGIS targets found

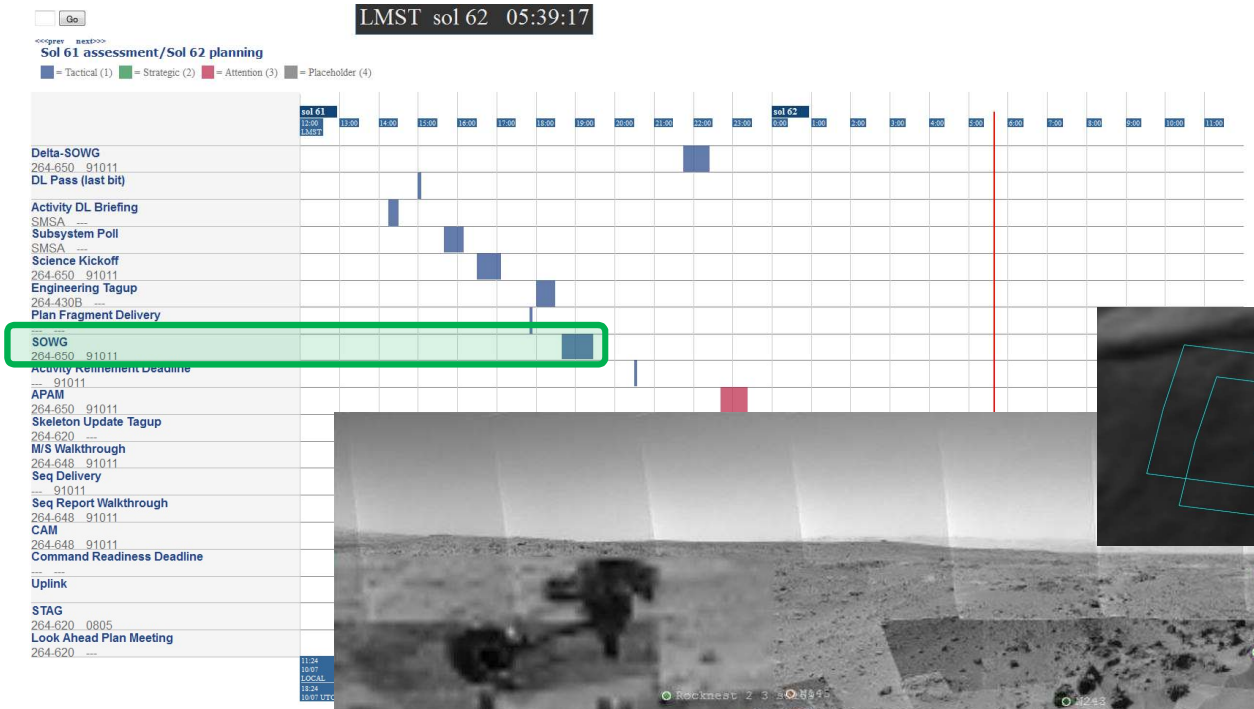
No sequences execution warnings raised by ARC

Bilan instrument :

- Activité déroulée ?
- Instrument Off ?
- Instrument Sun Safe ?
- Températures ?
- GO for planning ?

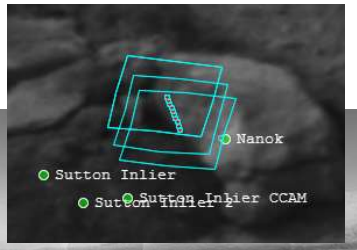


Préparation du Plan Sol n+1

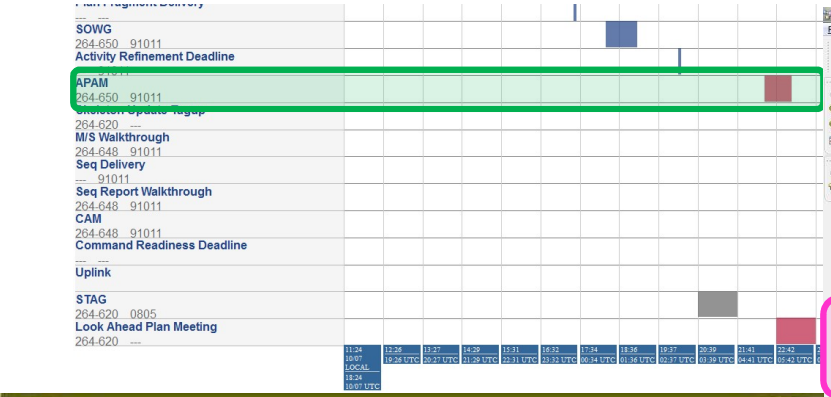


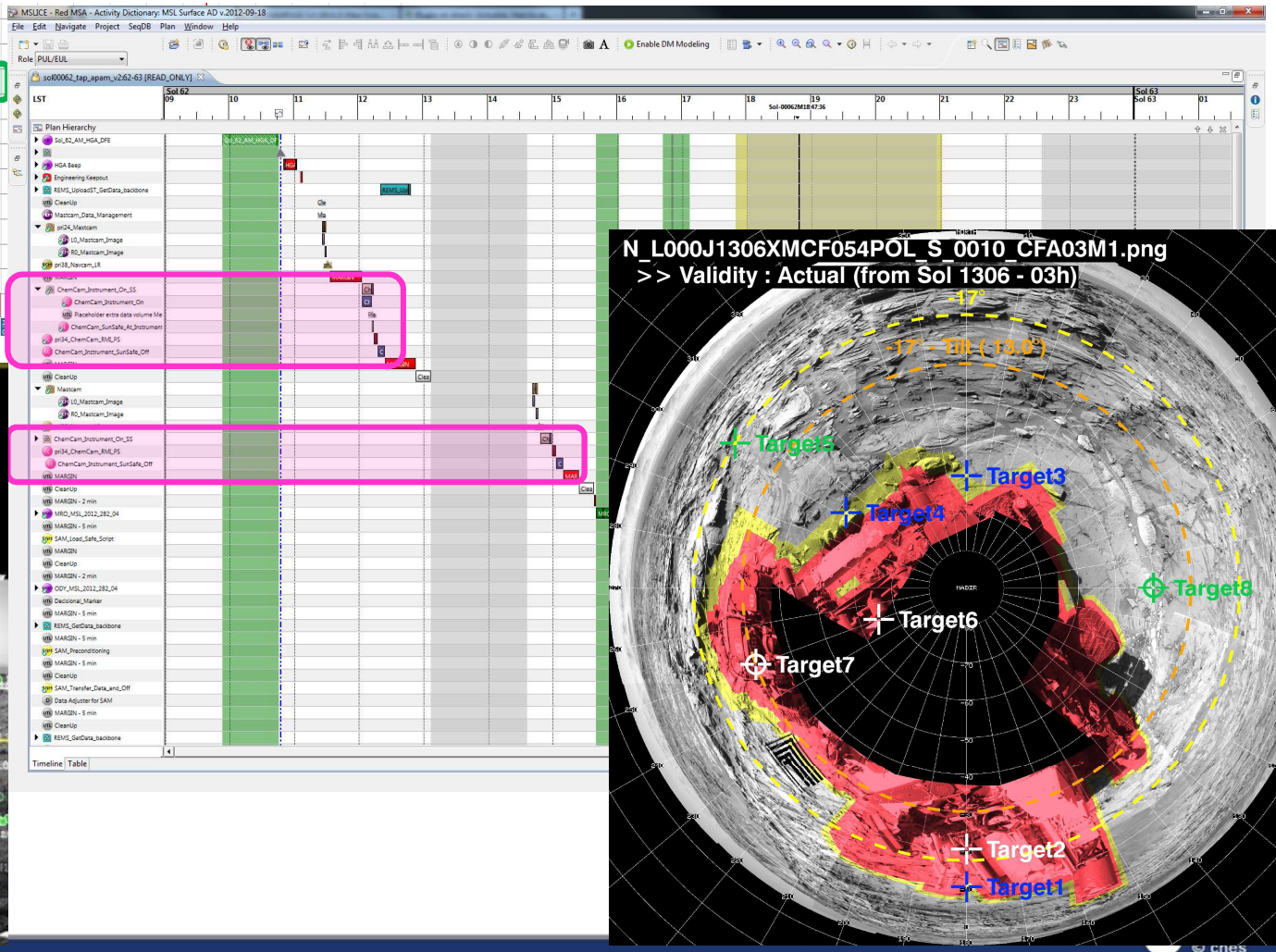
Principales observations:

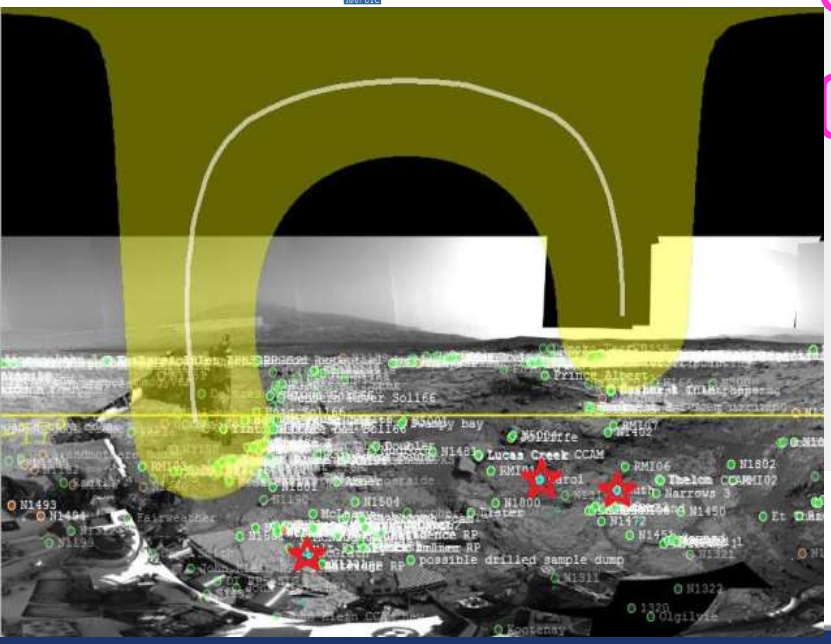
- Point
- Ligne 1x5 (V,H,D)
- Grille NxN
- Profil en profondeur



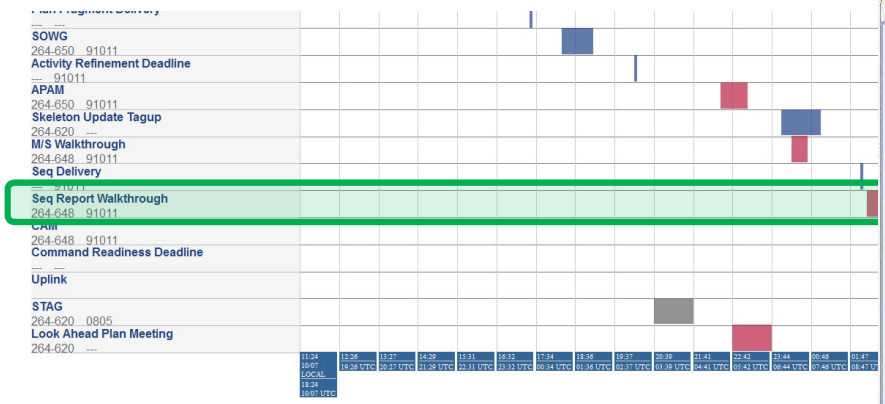
Validation du Plan Sol n+1

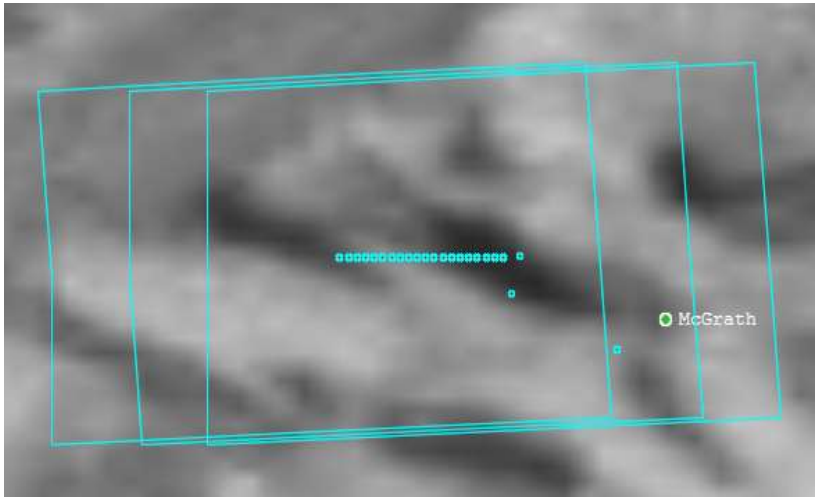






Livraison/Validation des séquences Sol n+1





[59:5:104] NAV_RIGHT_A mosaic | ccam03043.0000a.RLR_Grid_3x3_Kam_soil [ACCEPTED]

```
1  ##########################################
2  # Activity ChemCam_RMI_LIBS_RMI
3  # Author: CCAM_Cmd_Exp v7.3
4  # PUL Name: C. Yana (PUL1) / C. Donny (PUL2)
5  # RMI-LIBS 3x3 Raster-RMI Observation of Target: Kam
6  # Target (RNAV): Kam Range=3422mm
7  # Target (RNAV): Kam (XYZ)=(-2.648, 2.851, 0.182)
8  # Target (RNAV): Kam (Az deg,rad)=(131.052,2.28729)
9  # Target (RNAV): Kam (El deg,rad)=(-35.769,-0.62428)
10 # Actual corrected pointing for: Kam (XYZ)=(-2.629 2.879 0.191 )
11 # Way point for backlash compensation: -0.0872rad in AZ and -0.0872rad in El
12 # Change Log from expansion:
13 #   Target and waypoint data
14 ##################################
15 # Go to way-point: Correct target Az by -0.0872rad and correct target El by -0.0872rad
16 CCAM_PASV_SPECTRAL_OBS 77(priority) LL 0 AZEL_ABS 2.1888236 -0.7120364 0.0 NO_FOCUS 3435(mm) 0(count) 1(count) NONE
17 # Pre-LIBS RMI Image
18 CCAM_LASER_ENABLE
19 CCAM_RMI_OBS 56(priority) LL 0 XYZ -2.629 2.879 0.191 BASELINE 3435(mm) EXP_AUTO 50(msec) 0 0 1024(count) 1024(count) LOCO
20 # Active Spectral observation
21 # LIBS observation row 0
22 # LIBS Raster
23 CCAM_LASER_ENABLE
24 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 NO_MOTION 0.0 0.0 0.0 AF_OFFSET 3435(mm) YES NONE YES 0(count) 0(count) 30(count) NONE
25 CCAM_LASER_ENABLE
26 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 NO_MOTION 0.0 0.0 0.0 AF_OFFSET 3435(mm) YES NONE NO 0(count) 0(count) 30(count) FULL_STATS
27 # LIBS observation column 1
28 CCAM_LASER_ENABLE
29 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 AZEL_REL 0.0033 0.0 0.0 AF_OFFSET 3435(mm) YES NONE YES 0(count) 0(count) 30(count) NONE
30 CCAM_LASER_ENABLE
31 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 NO_MOTION 0.0 0.0 0.0 AF_OFFSET 3435(mm) YES NONE NO 0(count) 0(count) 30(count) FULL_STATS
32 # LIBS observation column 2
33 CCAM_LASER_ENABLE
34 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 AZEL_REL 0.0033 0.0 0.0 AF_OFFSET 3435(mm) YES NONE YES 0(count) 0(count) 30(count) NONE
35 CCAM_LASER_ENABLE
36 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 NO_MOTION 0.0 0.0 0.0 AF_OFFSET 3435(mm) YES NONE NO 0(count) 0(count) 30(count) FULL_STATS
37 # LIBS observation row 1
38 # Go to way-point (same as above using AZEL_ABS) and start position of raster (in XYZ)
39 CCAM_PASV_SPECTRAL_OBS 77(priority) LL 0 AZEL_ABS 2.1888236 -0.7120364 0.0 NO_FOCUS 3435(mm) 0(count) 1(count) NONE
40 CCAM_PASV_SPECTRAL_OBS 77(priority) LL 0 XYZ -2.629 2.879 0.191 NO_FOCUS 3435(mm) 0(count) 1(count) NONE
41 # LIBS Raster
42 # LIBS observation column 0
43 CCAM_LASER_ENABLE
44 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 AZEL_REL 0.0 0.0033 0.0 AF_OFFSET 3435(mm) YES NONE YES 0(count) 0(count) 30(count) NONE
45 CCAM_LASER_ENABLE
46 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 NO_MOTION 0.0 0.0 0.0 AF_OFFSET 3435(mm) YES NONE NO 0(count) 0(count) 30(count) FULL_STATS
47 # LIBS observation column 1
48 CCAM_LASER_ENABLE
49 CCAM_ACTV_SPECTRAL_OBS 56(priority) LL 0 AZEL_REL 0.0033 0.0 0.0 AF_OFFSET 3435(mm) YES NONE YES 0(count) 0(count) 30(count) NONE
50 CCAM_LASER_ENABLE
```

Séquences Validation:

- Flight Rules check ?
- Seq. Gen. modeling ?
- GO for Uplink ?

CONCLUSION : c'est un succès …

Bilan CCAM SOL # 1841

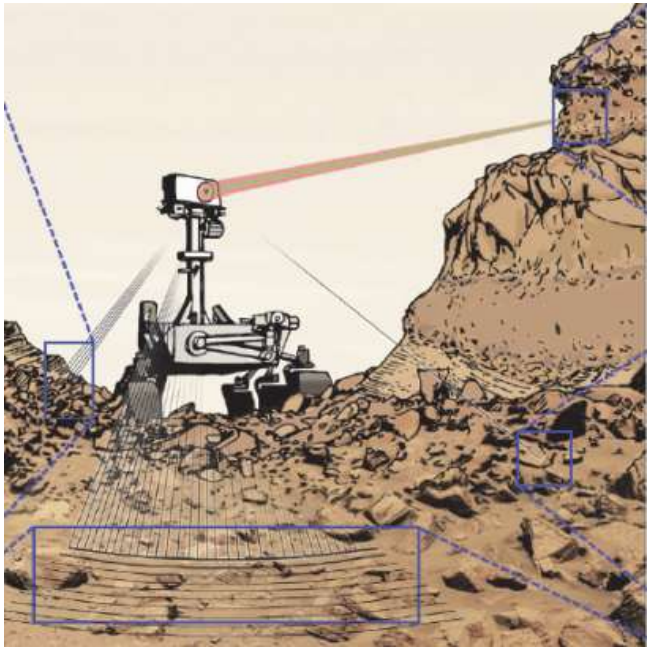
Working SOLs : 1099
Sequences : 2177
Nb of Mars Targets : 2072
LIBS points on Mars : 15912
LIBS points on Cal Targets : 859
Laser shots : 504694
Target Images of Mars: 8020
Cal Target Images: 1972
Data files (EDR): 54359

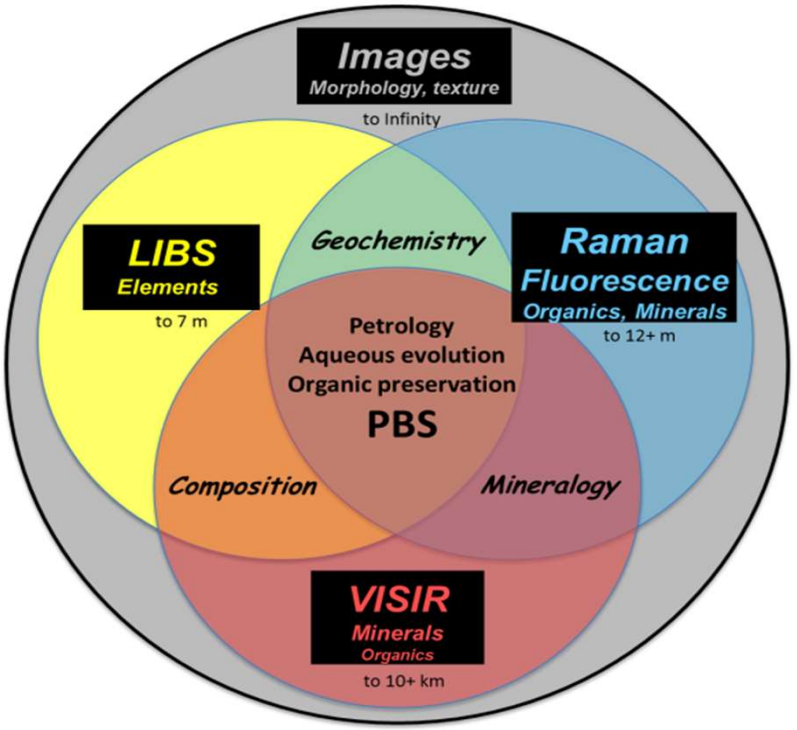
- Les instruments français fonctionnent très bien
- C'est un succès scientifique, technique et médiatique
- Source de motivation pour les chercheurs, les ingénieurs et les jeunes
- Très bonne collaboration bilatérale avec les USA
- Très bonnes synergies entre le CNES et les laboratoires de recherche

Mars 2020 & SuperCam

Mars 2020 commencera la recherche de traces de vie (décollage: 2020)

SuperCam fournira une mesure minéralogique et chimique à petite échelle





Partenariat CNRS – Universités – CNES

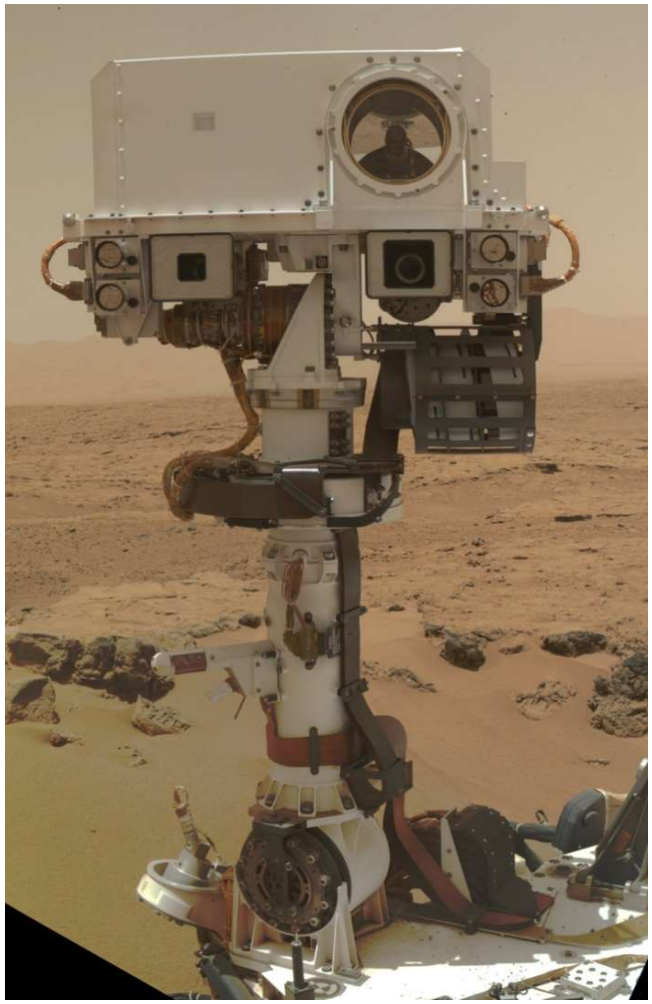
30 scientifiques (Astro., GeoSciences, Phys.) ~100 ETP ITA, Ing. CNES (Phases A-E1)

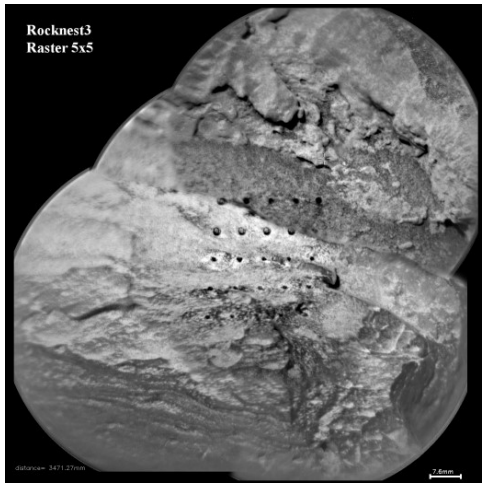
Opérations au FIMOC (Phase E2)

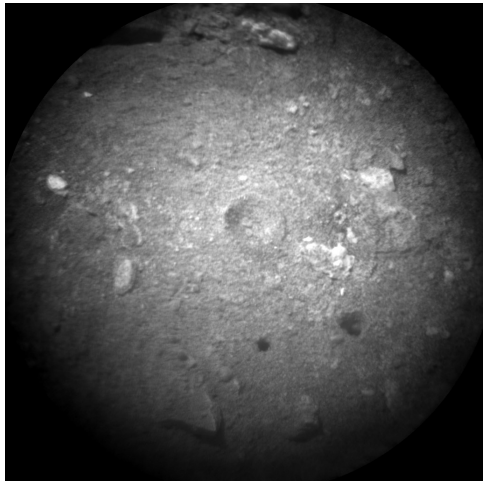
Merci de votre Attention.

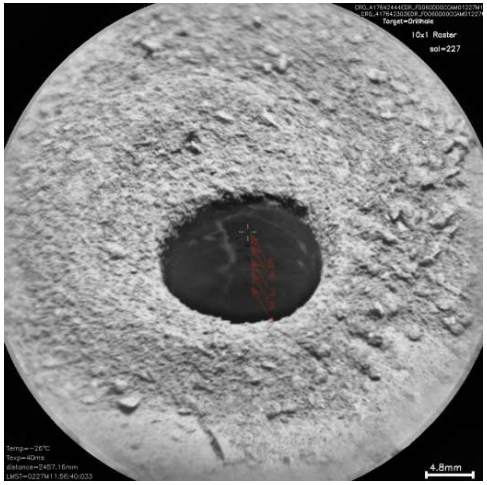
Questions ?

Quelques résultats techniques remarquables

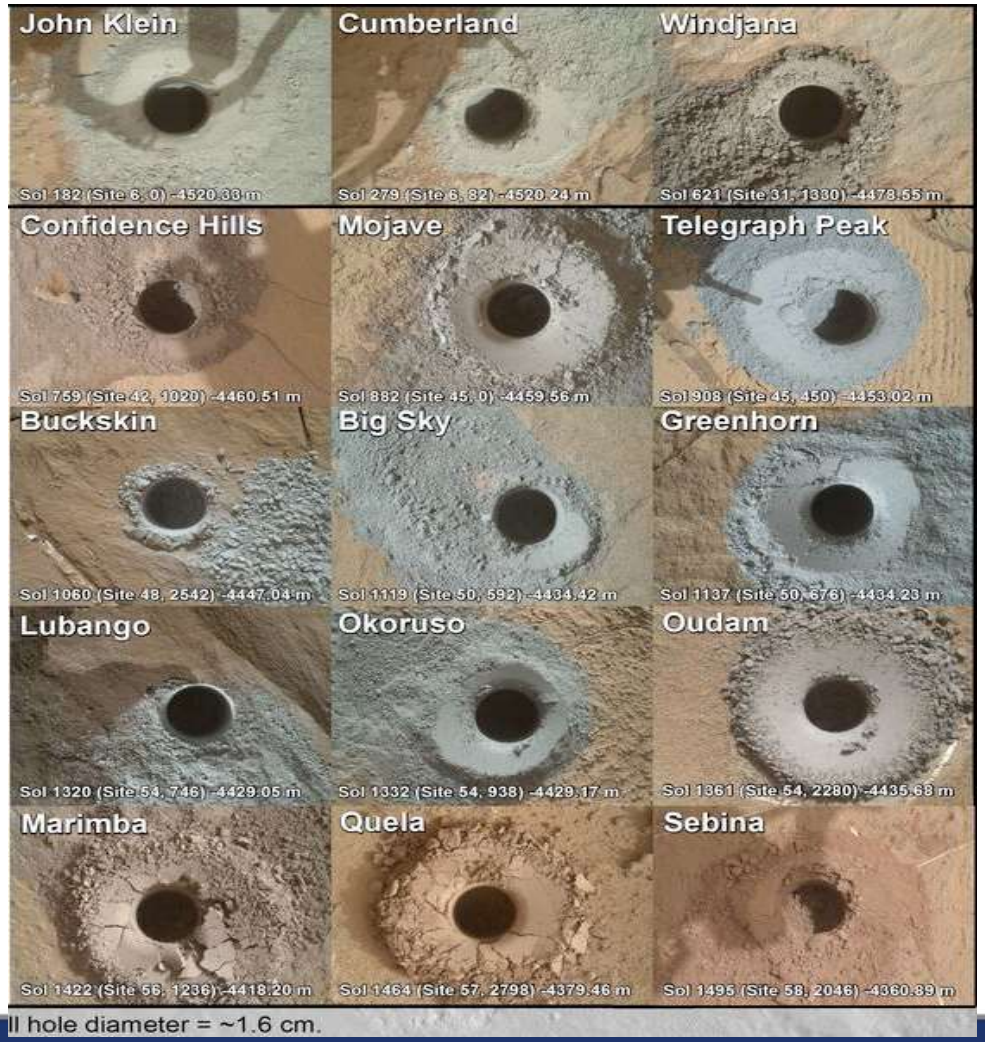




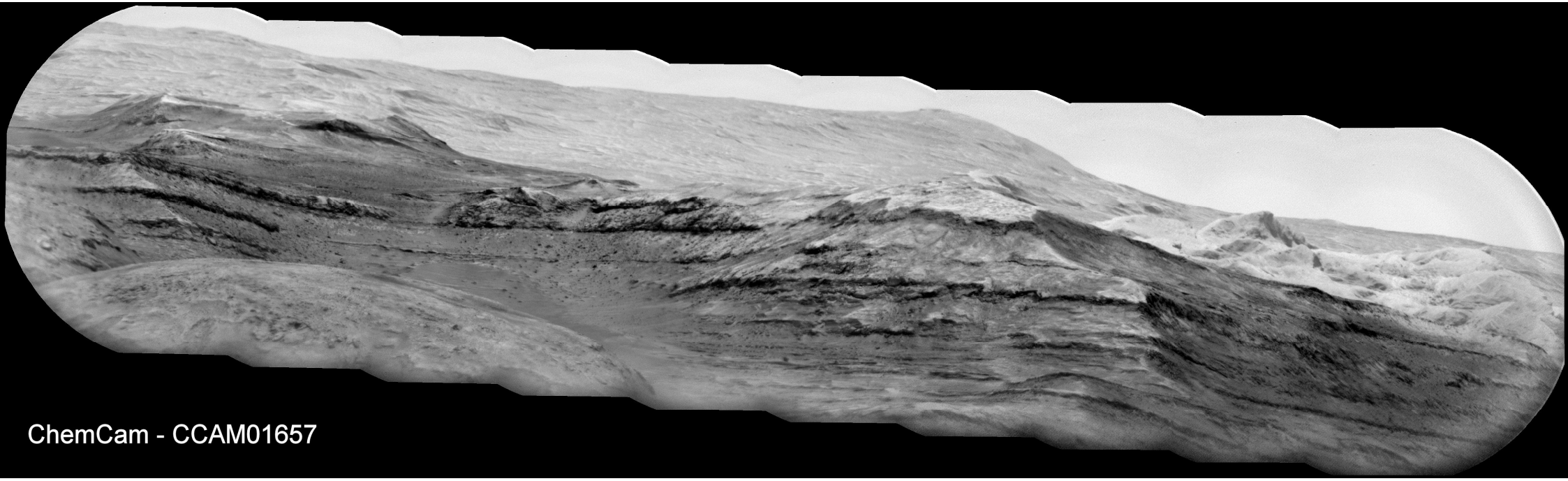




Quelques résultats techniques remarquables

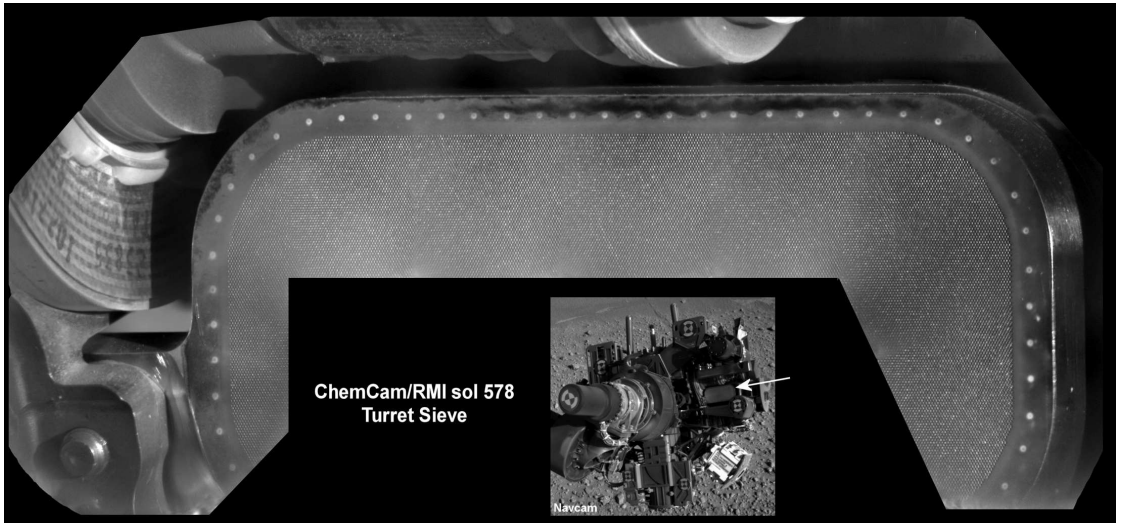


Long distance RMI Mosaic

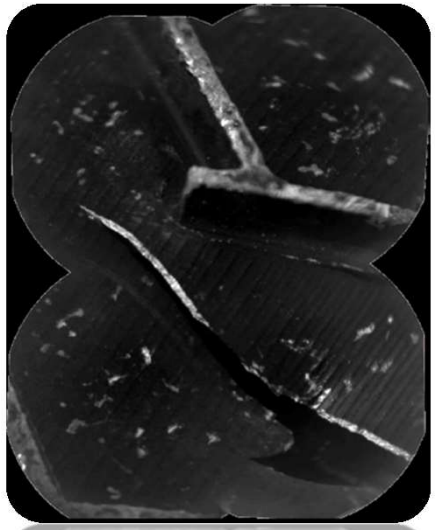


Quelques images d'inspection technique du Rover

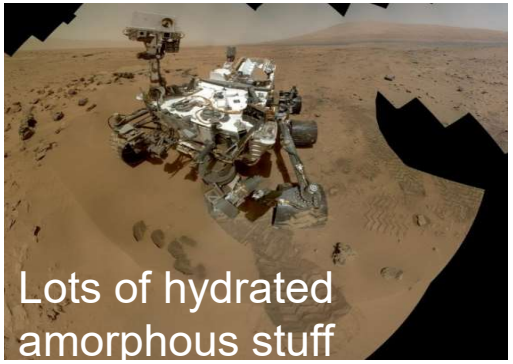
Drill bit, sol 172



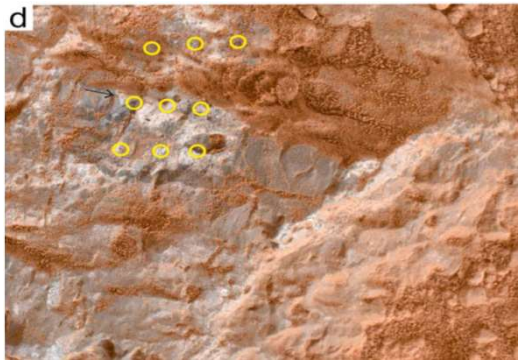
Wheel inspection, sol 520



Quelques Résultats Scientifiques




Feldspar-rich magmatic rocks (ancient crust)

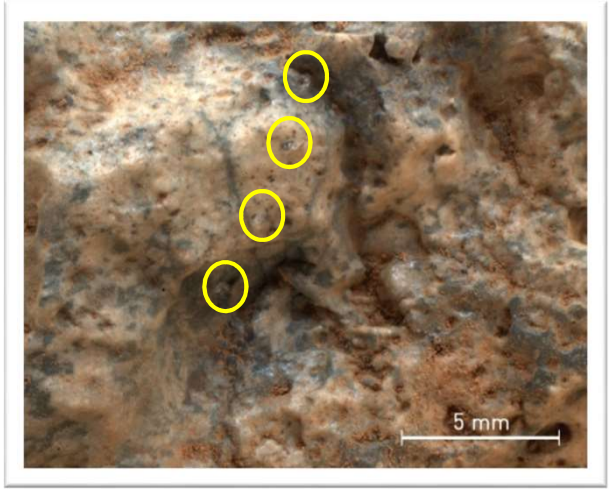


Conglomerates as proxy of different sediment sources


Potassic sedimentary rocks
+ manganese-rich coatings
+ other metals, such as Zn


Detection of fluorine in aluminosilicates and sandstones

Résultat scientifique : géologie



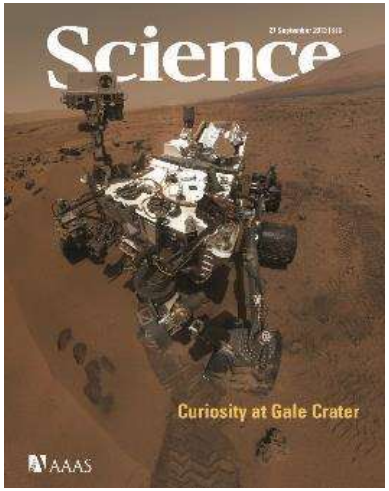
Alerte presse CNRS (15 juillet 2015):
Curiosity trouve des traces d'une croûte continentale primitive sur Mars

- La surface de Mars n'est pas constituée uniquement de roches basaltiques.
- ChemCam a mesuré la composition de roches plus claires, riches en feldspaths et parfois en quartz.
- Ces roches sont similaires à la croûte continentale granitique sur Terre.
- Il s'agit de la première preuve de l'existence d'une croûte continentale sur Mars.

Sautter et al., Nature Geos., 2014

Résultats combinés de la Charge Utile MSL

- ✓ Présence d'eau liquide
- ✓ Un pH relativement neutre
- ✓ Une salinité relativement faible
- ✓ Milieu réducteur
- ✓ Probable détection de carbone



➔Mars fut DANS LE PASSE habitable!

- **Pendant combien de temps?**
- **A quelle époque exactement?**

} ***Objectifs de la mission étendue***