Mars Science Laboratory (MSL) Opportunity Rover

Pyrotechnic Mechanisms Heritage and Implementation

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AIAA-JPC

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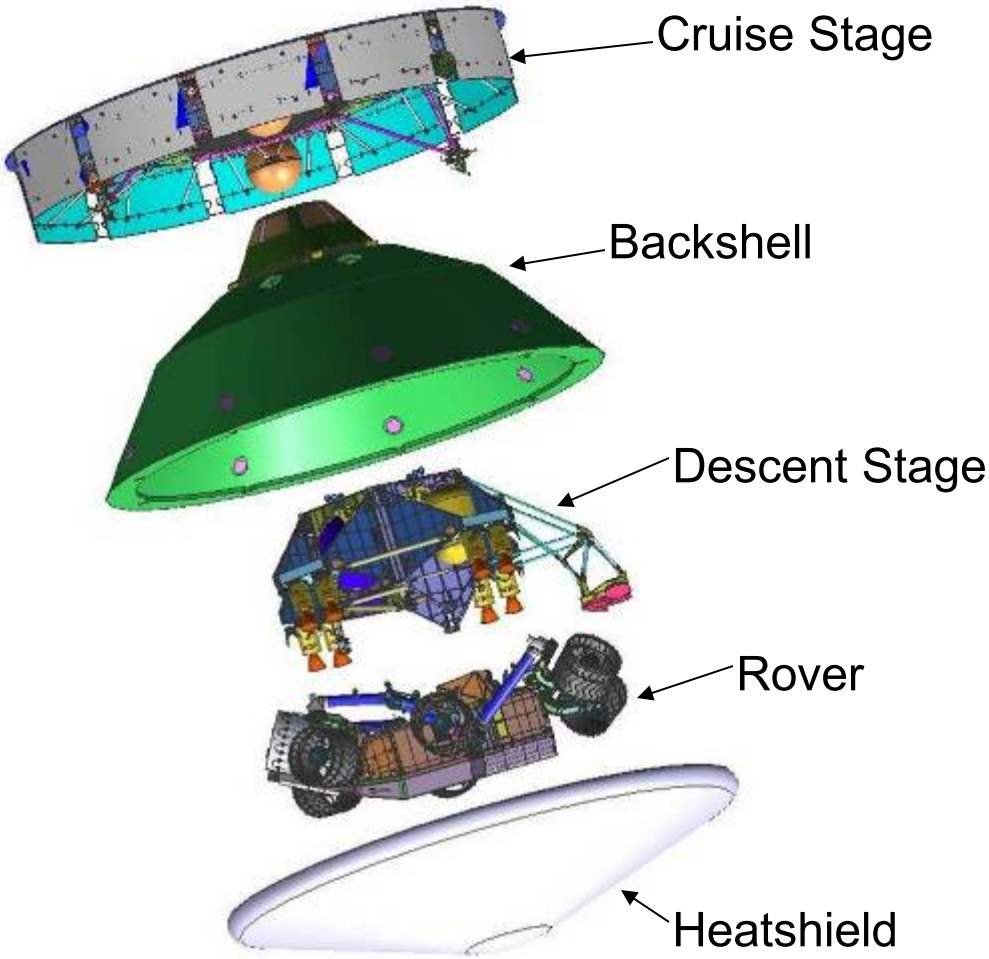
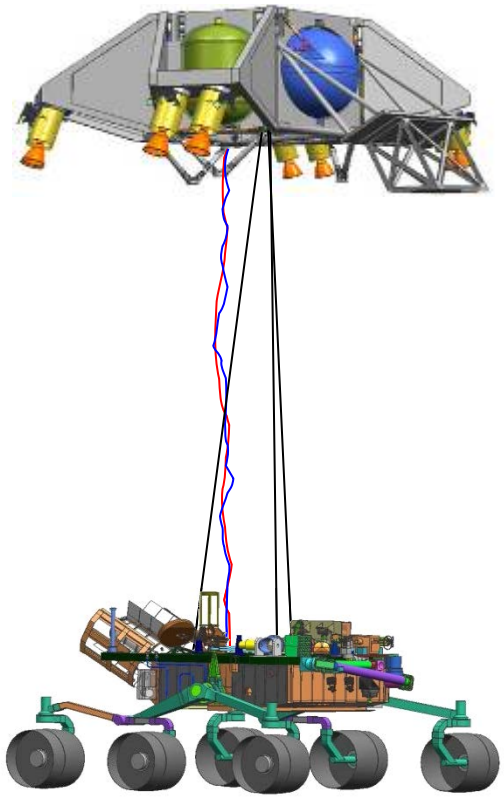
San Jose, California

AGENDA

- Spacecraft Elements
- Entry, Descent and Landing (EDL) Timeline
- Device Heritage and Development
  - 5/8” Sep Nut
  - 3/8” Sep Nut
  - 5/8” Cable Cutter
  - 1/4” Cable Cutter
- Cruise Stage Pyro’s
  - Heat Rejection System (HRS) Thruster
- Backshell Pyro’s
- Descent Stage Pyro’s
- Rover Pyro’s

MSL Spacecraft Elements

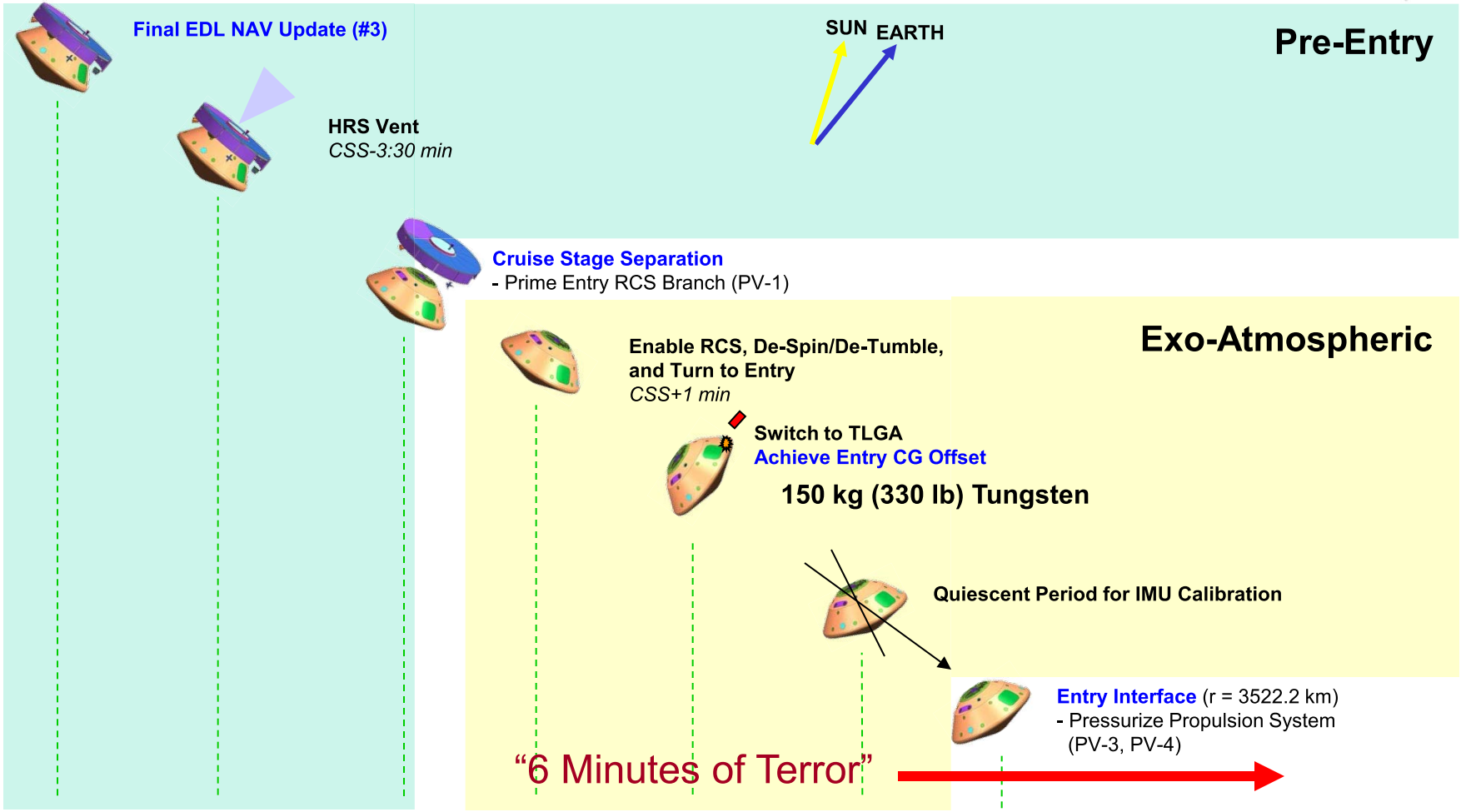




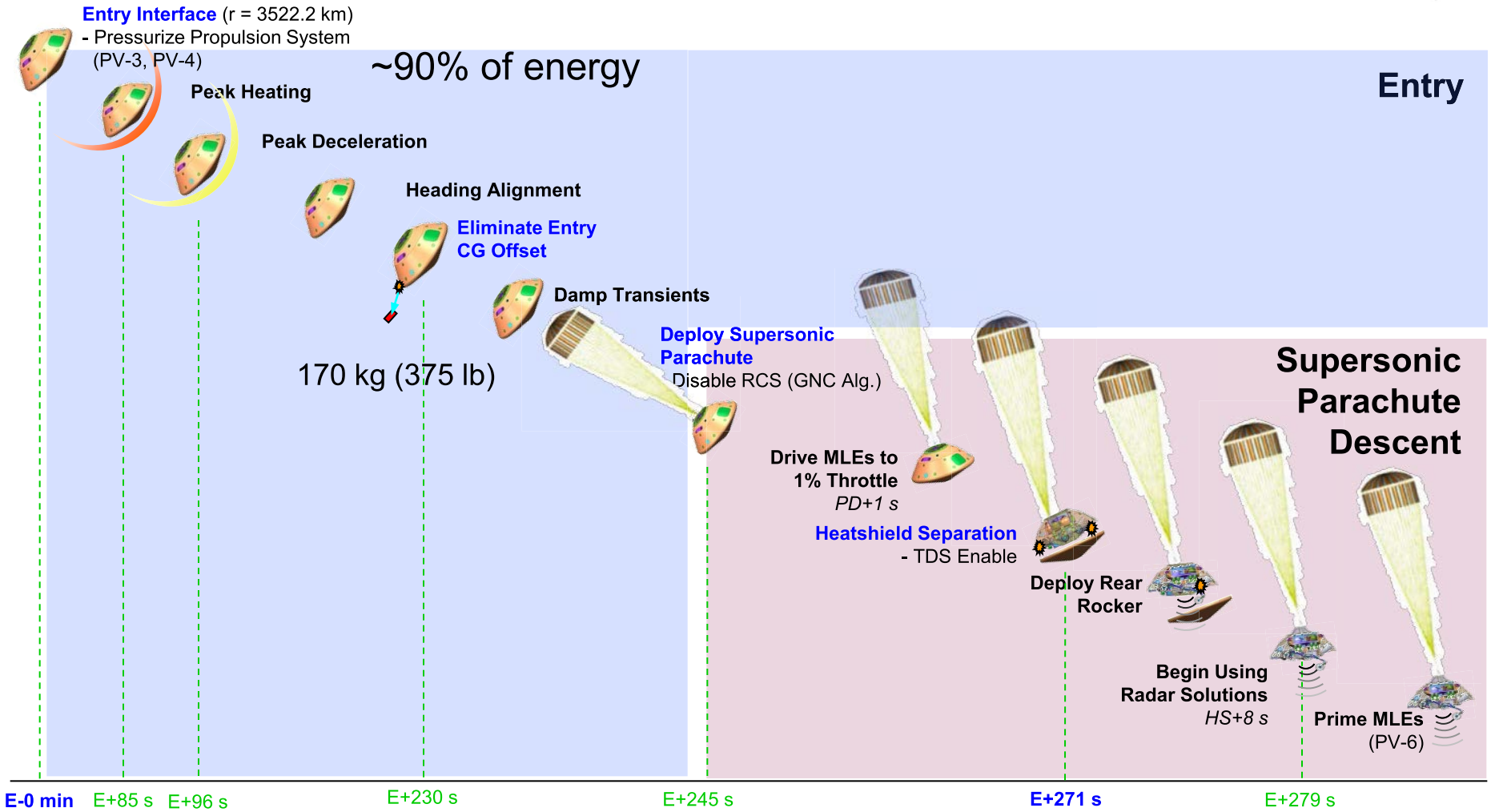
Sky Crane Maneuver

Backshell + Heatshield = Aeroshell

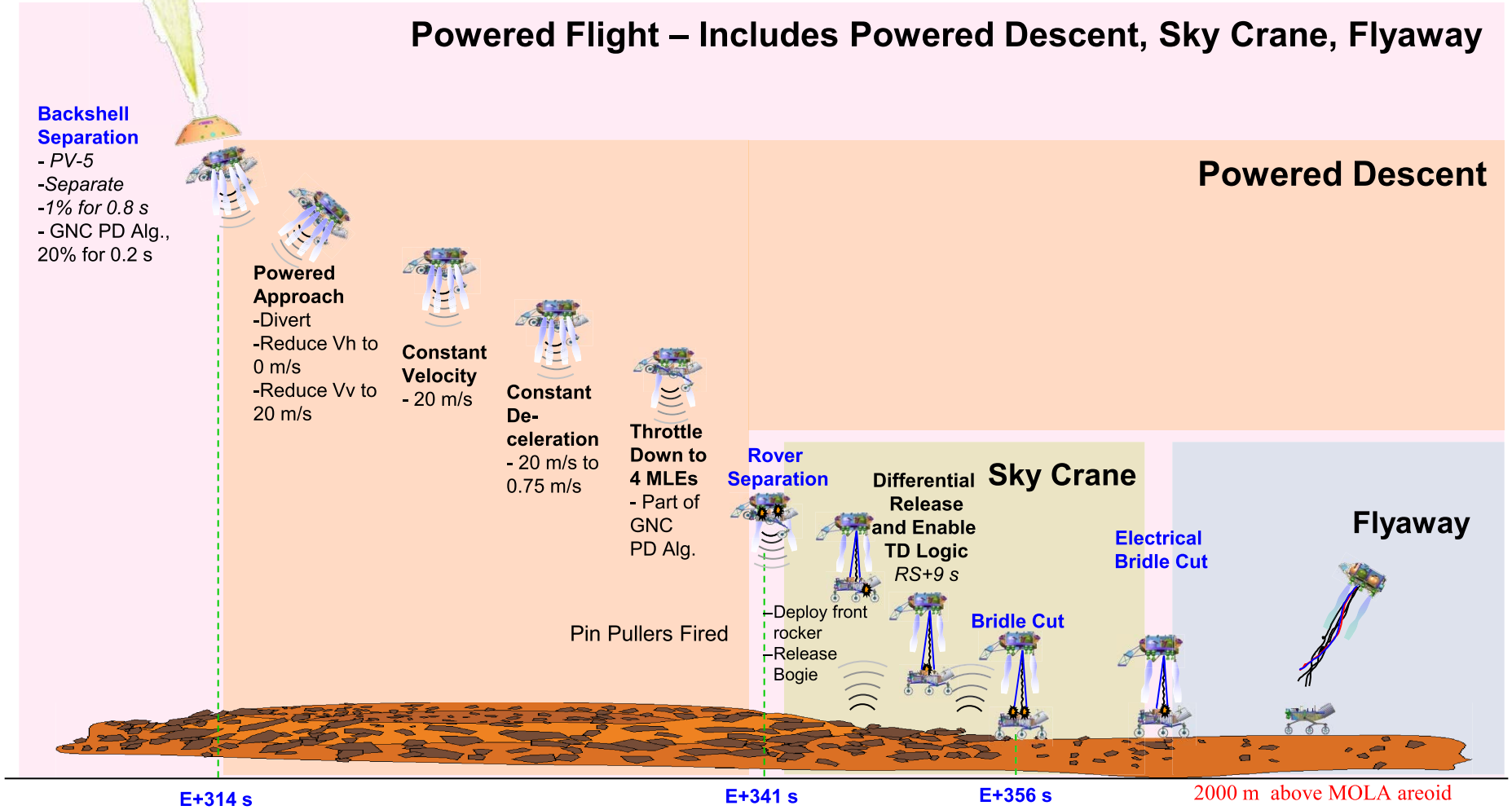
EDL Event Timeline 1/3



EDL Event Timeline 2/3

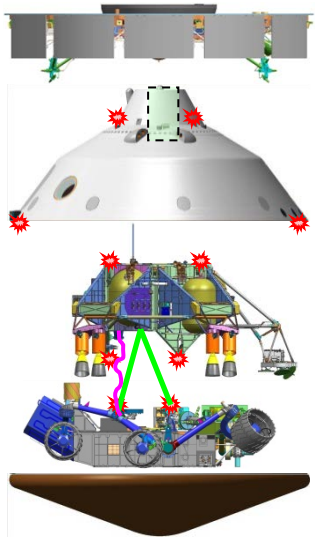


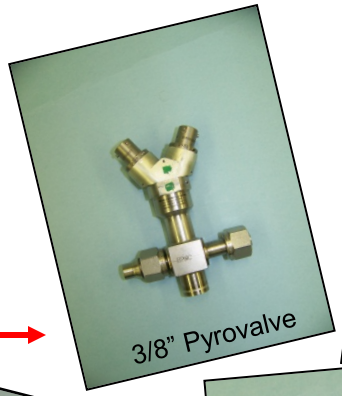
EDL Event Timeline 3/3

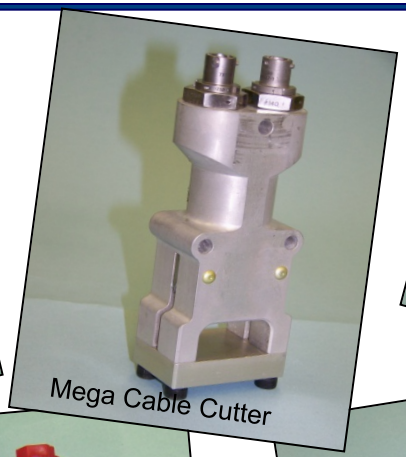


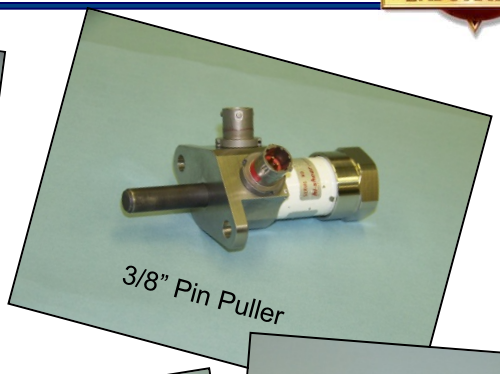
EDL Video

EDL Pyro Devices



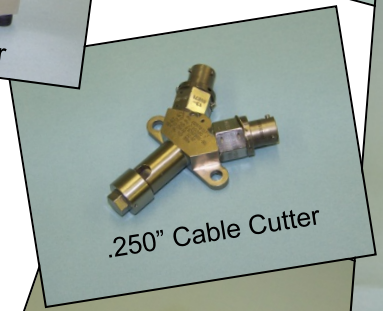

3/8" Pyrovalve


Mega Cable Cutter

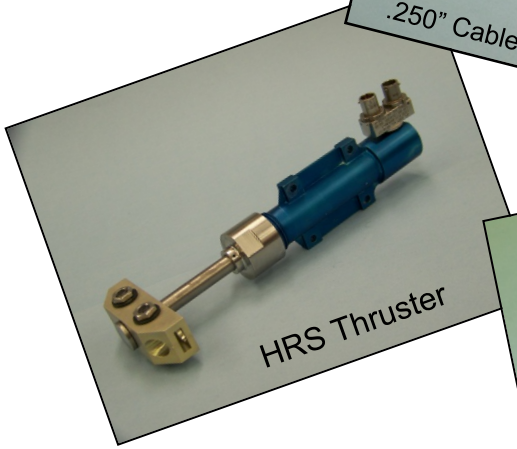

3/8" Pin Puller

.250" Cable Cutter

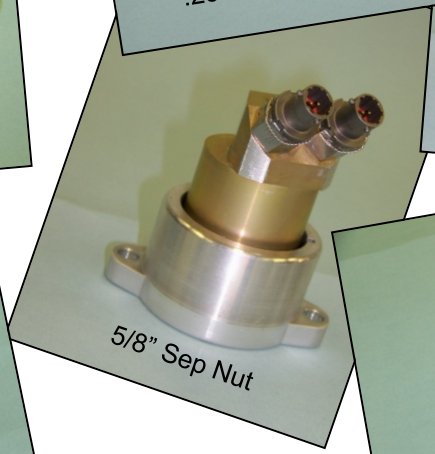
3/4" Pyrovalve

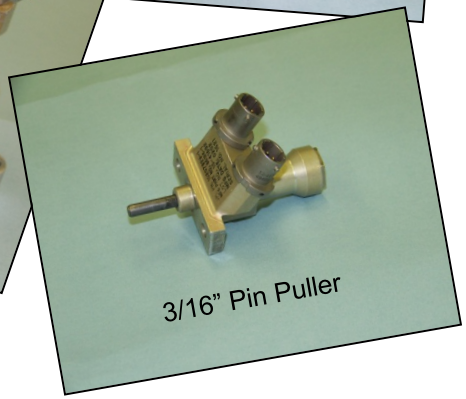

.250" Cable Cutter

.5/8" Cable Cutter


HRS Thruster

3/8" Sep Nut


5/8" Sep Nut


3/16" Pin Puller

Hardware Development

- 5/8” Sep Nut Pyroshock Mitigation
  - 50 firings evaluating various materials for mounting
    - Met-L-Flex Bushings
    - Crushable honeycomb “washer”
- Heat Rejection System (HRS) Retraction Thruster
  - Retracts 2 X 3/8” SST tubes from CS/Aeroshell interface
  - Thruster pistion/bore based on 5/8” Cable Cutter
  - Uses dual initiated 5/8” cable cutter booster
- CS/DS/Rover Interface Cable Cutters
  - Initially two “Mega” Cable Cutters
  - Final Design was one “Mega” Cable Cutter and two 5/8” Cutters

5/8” Sep Nut Heritage and Shock Mitigation

Crushable Cushion Incorporated

Met-L-Flex Bushings Incorporated

3/8” Sep Nut Heritage

Evolution of 3/8” Separation Nut Design

Magellan
MMA
c. 1983
6,000 lb_f tension
Dual NSI

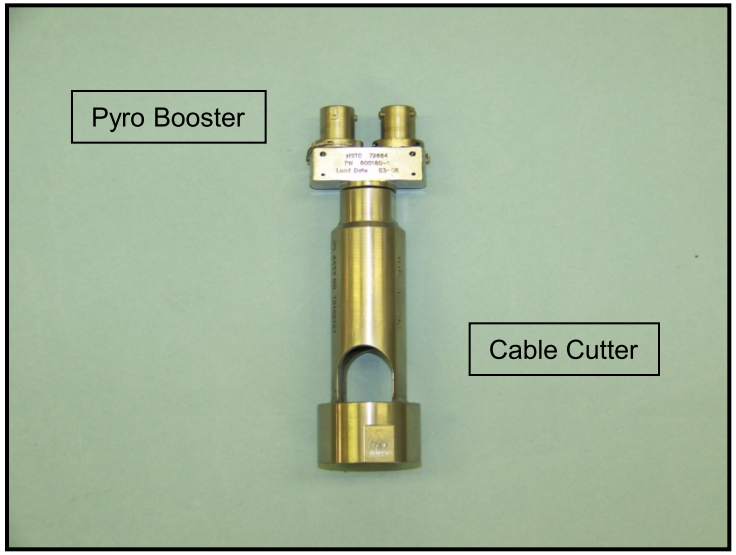
MER Petal Separation
JPL
2002
12,000 lb_f tension

TOPEX Poseidon
Fairchild
c. 1990
13,250 lb_f tension
Dual NSI/Booster

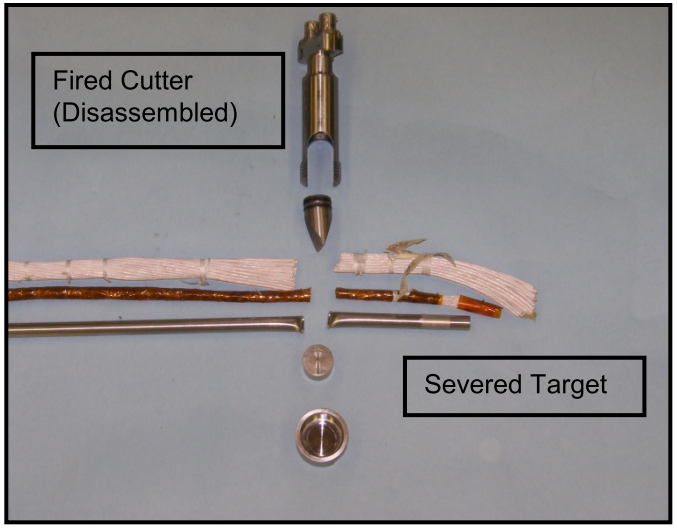
Pathfinder – MER – MSL – (SMAP)
JPL
1995 – 2002 – 2010
12,000 lb_f tension
Dual NSI/Booster
MSL Heatshield and
Balance Mass Separation

5/8” Cable Cutters

- Developed for Pathfinder c.1995
- 5/8” Cable Bundle
- Candidate for Bridle Cutter
- (1 unit total)

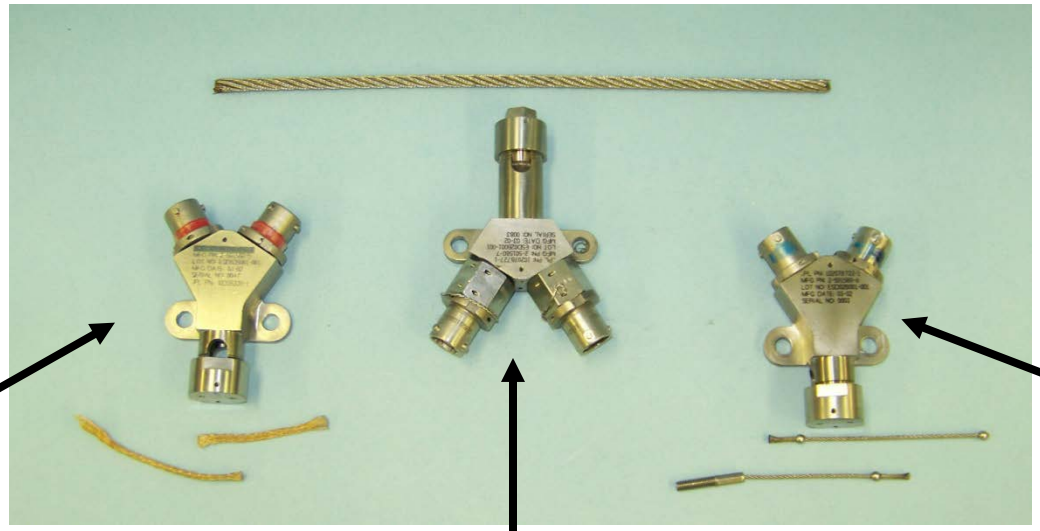


- Used on MER c. 2003
- Cruise Stage Separation
- Lander Petal Cutter
- (2 units total)



- Used on MSL c. 2010
- Cruise Stage Separation
- DS, CS & Rover Sep
- RSM, BUD, HS cabling
- (12 units total)

1/4” Cable Cutters



MER Air Bag Cutter
(2) 0.080” Vectran cords
(4 units)

MER Wheel Release Cutter
.188 Steel Cable
(6 units)

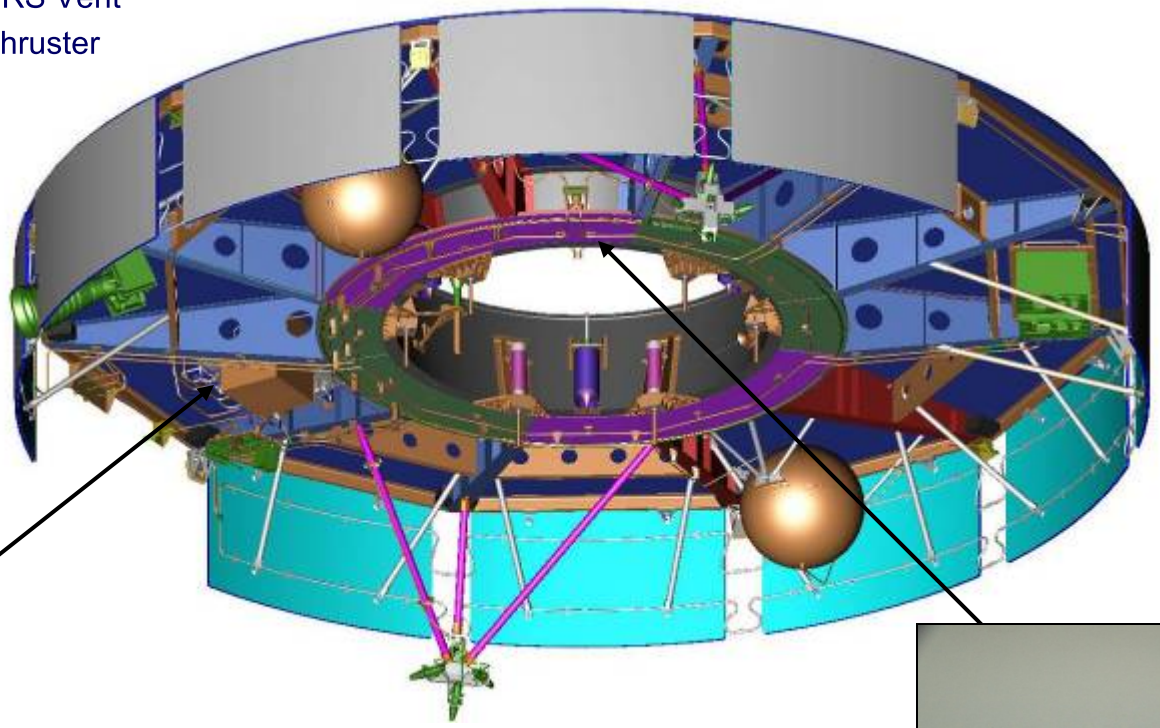
MER IDD Cable Cutter
0.050” steel cable
(1 unit)

MSL Applications:

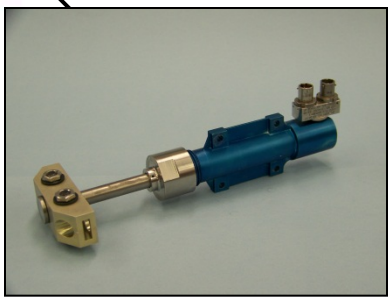
- Robotic Arm (2 units)
- Spare Drill Bit Box Covers (2 units)
- HazCam Covers (3 units)
- Heritage is from Pathfinder, Cassini, MER and stretches back to the Viking Moon Lander

Pyro's: CS Pyro's

- Cruise Stage Pyro's
  - (4) 3/8" Pyrovalves HRS Vent
  - (1) HRS Retraction Thruster



Pyrovalve
(4)
Boosters (4)
NSI's (8)

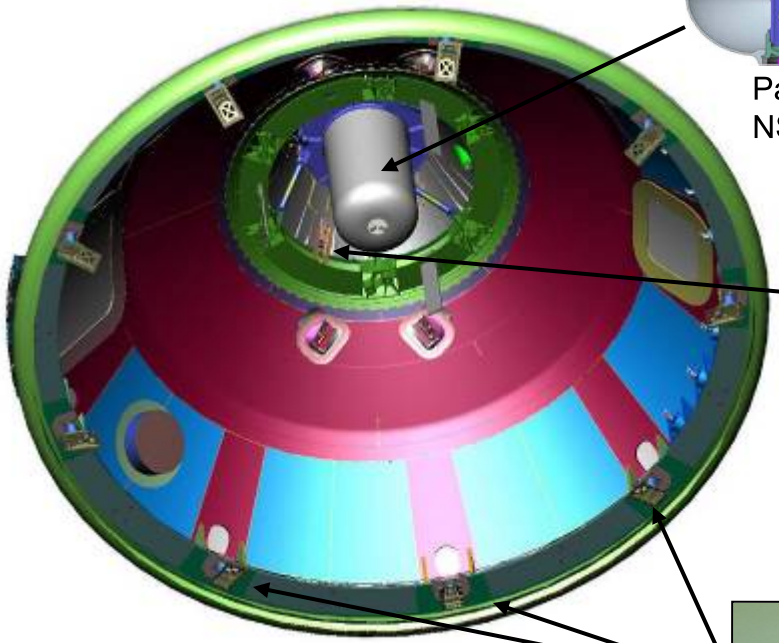


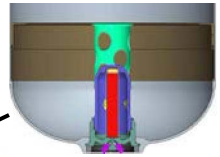
HRS Retraction Thruster (1)
Booster (1)
NSI's (2)

HRS Thruster Video

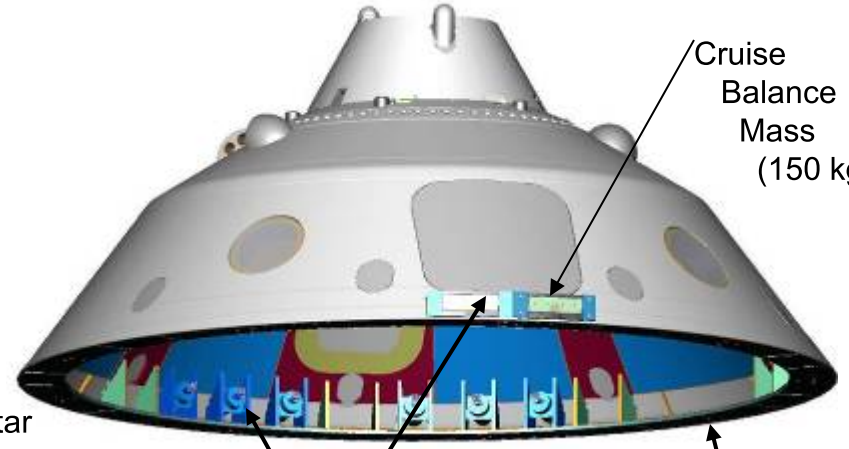
Pyros: Backshell

- Backshell Pyro's
  - (1) Mega Cable Cutters
  - (2) 5/8" Cable Cutters
  - (1) Parachute Mortar
  - (2) Cruise Balance Mass 3/8" Sep Nuts
  - (6) Entry Balance Mass 3/8" Sep Nuts
  - (1) MEDLI 5/8" Cable Cutter
  - (9) Heatshield 3/8" Sep Nuts





Parachute Mortar
NSI's (2)



Cruise
Balance
Mass
(150 kg)

Entry
Balance Mass
(170 kg)

Mega Cutters (1)
Boosters (4)
NSI's (4)

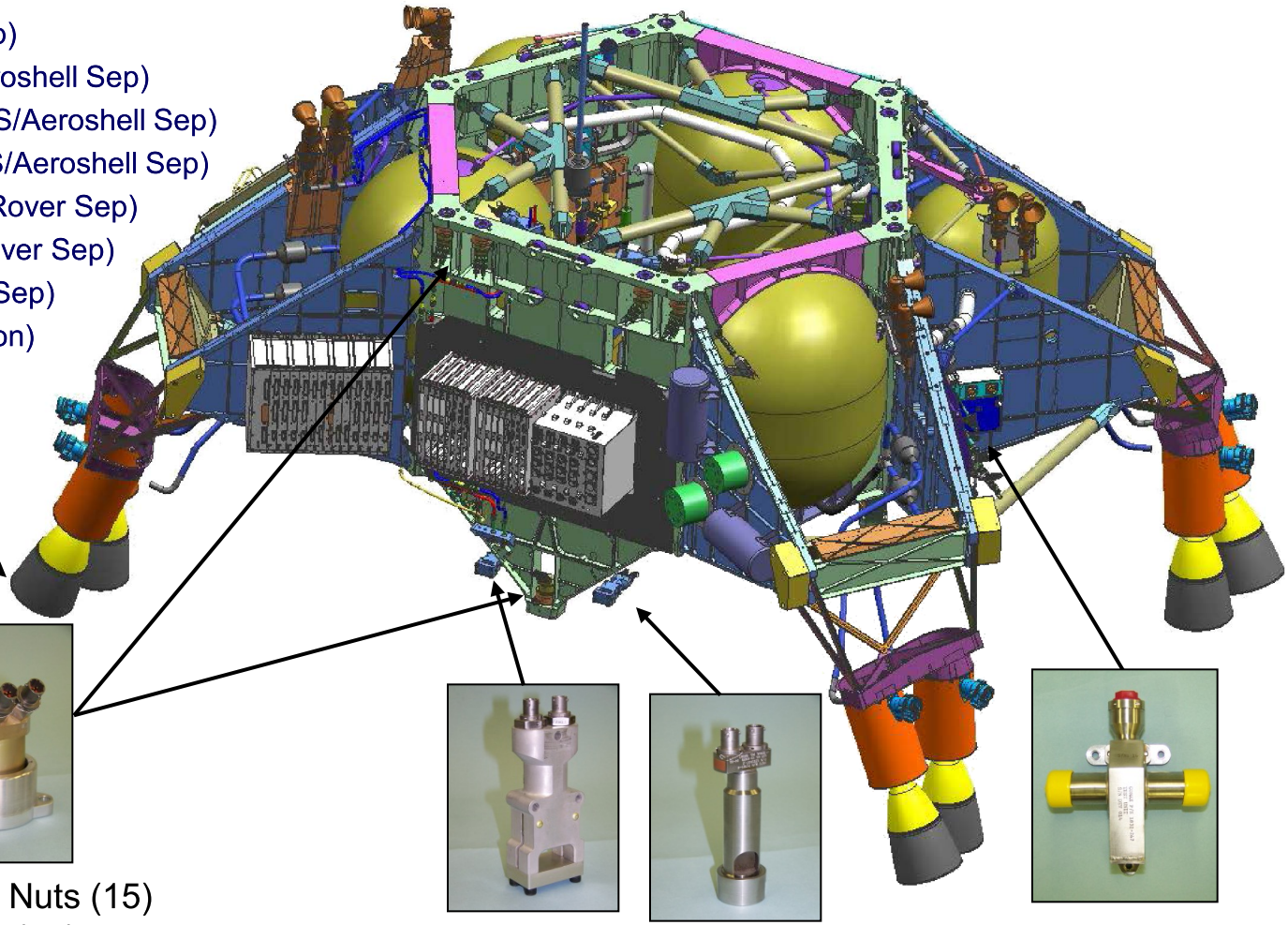
3/8" Sep Nuts (8)
Boosters (16)
NSI's (16)

5/8" Cable Cutter (3)
Boosters (1)
NSI's (2)
MEDLI HS Cable Cut

3/8" Sep Nuts (9)
Boosters (18)
NSI's (18)
Heatshield Sep

Pyros: Descent Stage

- Descent Stage Pyro's
  - (6) 5/8" Sep Nuts (CS Sep)
  - (6) 5/8" Sep Nuts (DS/Aeroshell Sep)
  - (1) Mega Cable Cutter (DS/Aeroshell Sep)
  - (2) 5/8" Cable Cutters (DS/Aeroshell Sep)
  - (1) Mega Cable Cutters (Rover Sep)
  - (2) 5/8" Cable Cutters (Rover Sep)
  - (3) 5/8" Sep Nuts (Rover Sep)
  - (16) Pyrovalves (Propulsion)



5/8" Sep Nuts (15)
Boosters (30)
NSI's (30)

Mega Cutters (1)
Boosters (8)
NSI's (8)

5/8" Cable Cutter (2)
Boosters (2)
NSI's (4)

Pyrovalves (16)
Boosters (16)
NSI's (32)

Video CS & DS Sep

Video DS Cable Cutters Firing Prior to Rover Separation

Pyros: Rover Sep/Deployments

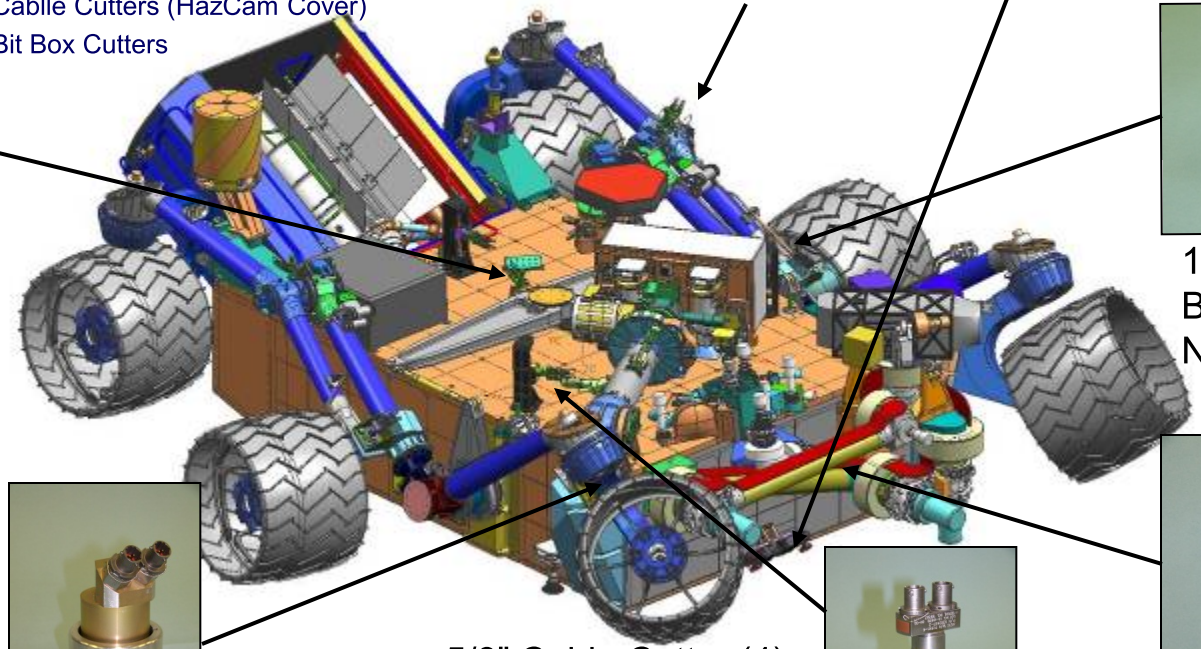
- Rover Pyro's
  - (3) 5/8" Bridle Cable Cutters
  - (1) 5/8" E-Bridle (Umbilical) Cable Cutter
  - (2) 3/16" Bogie Pose Pin Puller
  - (1) 3/8" Differential Unlock Pin Puller
  - (1) 5/8" Cable Cutter (RSM)
  - (2) 1/2" Sep Nuts (Rover Center Wheels)
  - (4) 5/8" Sep Nuts (Rover Front and Rear Wheels)
  - (1) M8 Sep Nut (HGA Release – Provided by Sener)
  - (2) 1/4" Side Aperture Cable Cutters (Robotic Arm)
  - (3) 1/4" Cablle Cutters (HazCam Cover)
  - (2) 1/4" Bit Box Cutters

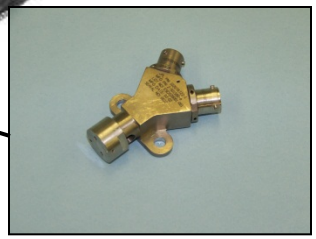
3/16" Pin Puller (2)
NSI's (4)

1/4" Cable Cutter (3)
NSI's (6)

3/8" Pin Puller (1)
NSI's (2)

1/2" Sep Nuts (2)
Boosters (4)
NSI's (4)





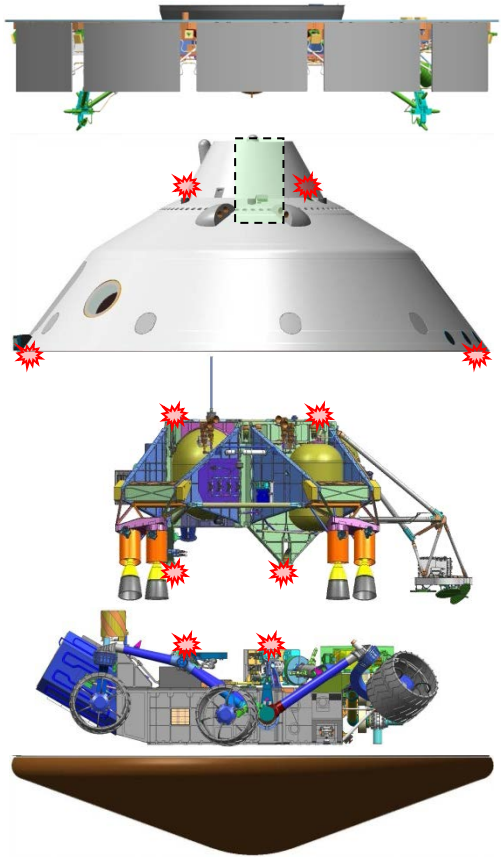
1/4" Cable Cutter (2)
NSI's (4)

5/8" Sep Nuts (4)
Boosters (8)
NSI's (8)

5/8" Cable Cutter (4)
Boosters (4)
NSI's (8)

Video Full Motion Drop Test

MSL Pyro Summary



- 39 Sep Nuts
  - (19) 5/8” Sep Nuts
  - (17) 3/8” Sep Nuts
  - (2) 1/2” Sep Nuts
  - (1) M8 Sep Nut
- 22 Cable Cutters
  - (3) Mega Cable Cutters
  - (12) 5/8” Cable Cutters
  - (7) 1/4” Cable Cutters
- 3 Pin Pullers
  - (2) 3/16” Pin Pullers
  - (1) 3/8” Pin Puller
- 20 Pyro Valves
  - (12) 3/8” Hi Pressure Pyro Valves
  - (8) 3/4” Hi Flow Pyro Valves
- 1 HRS Retraction Thruster
- 1 Parachute Mortar

TOTAL: 86 Devices, 172 NASA Standard Initiators (NSI’s)