親機子機分離機構を備えた月惑星探査機着陸機構の2次元シミュレーション

Two-Dimensional Simulation of Lunar/Planetary Exploration Spacecraft Landing Mechanism Using BESM

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This study discusses a lunar/planetary spacecraft landing mechanism using energy conversion. A part of the authors has already proposed Base-Extension Separation landing Mechanism (BESM) and its effectiveness was confirmed in one-dimentional simulations and experiments. This study shows two-dimensional response analysis using BESM. The effectiveness of BESM for falling to slopes is verified.

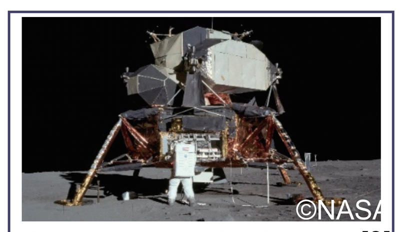
Background

◆ Explorations of the lunar attract attention

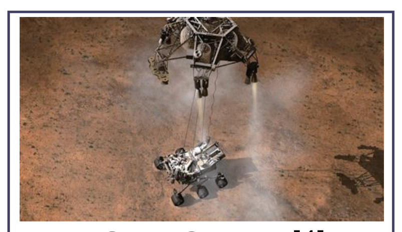
Requirement: To realize soft landing on severe regions… for example slopes or steps.

◆ Previous methods and their problems

Airbag[2]

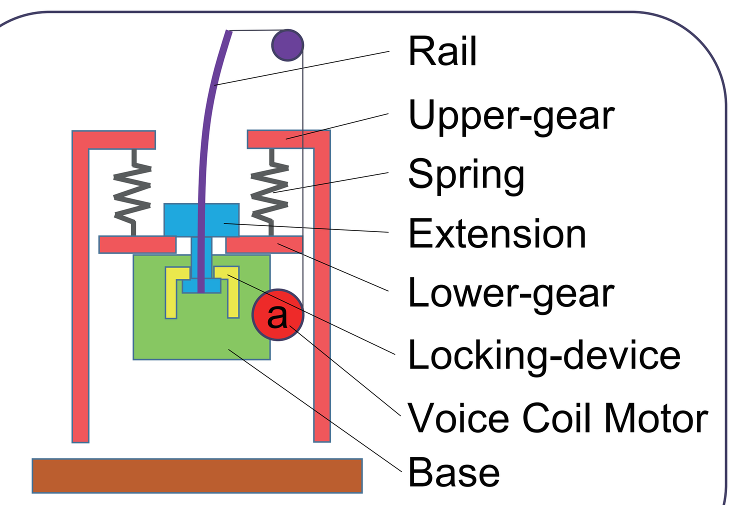


Honeycomb Crash[3]


Sky Crane[4]

Problems
- High rebound
- Impossibility to reuse
- Complex control

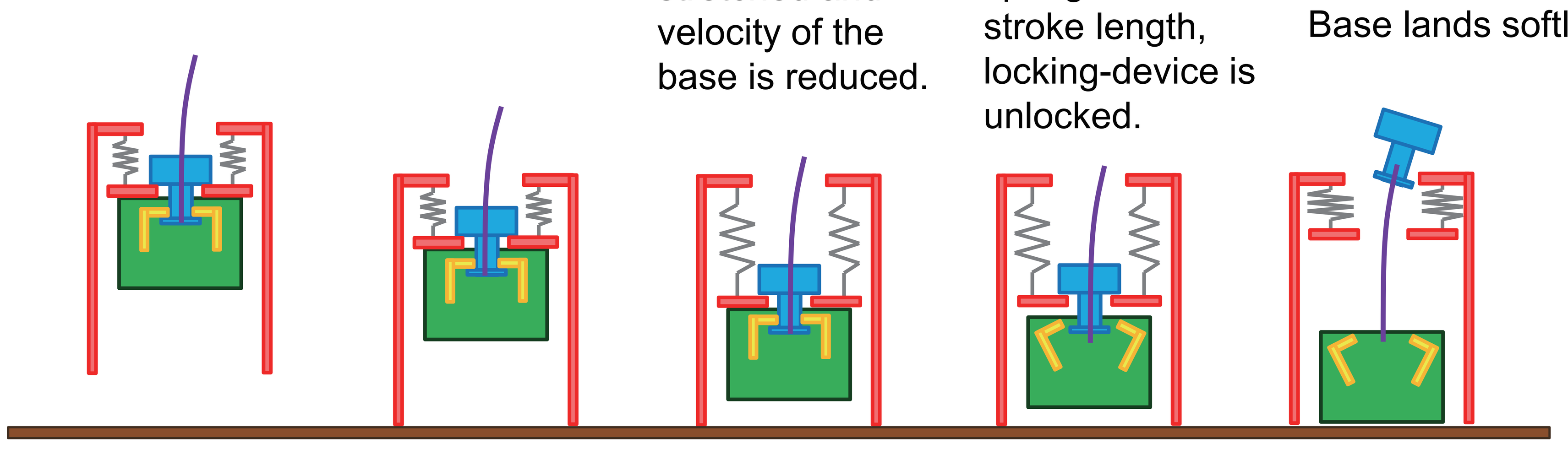
BESM
Base-Extension Separation landing Mechanism



Components of BESM

BESM can realize…
- ☐ Low rebound
- ☐ Reuse
- ☐ Passive landing

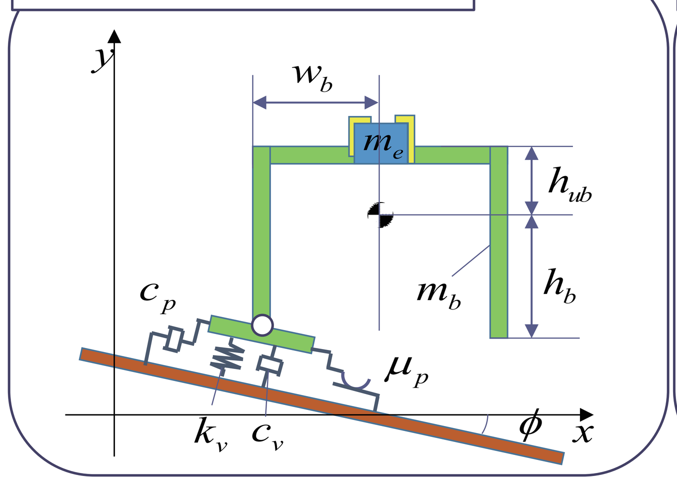
1. Falling
2. Landing
3. Spring is stretched and velocity of the base is reduced.
4. When the springs reach stroke length, locking-device is unlocked.
5. Extension is launched. Base lands softly.



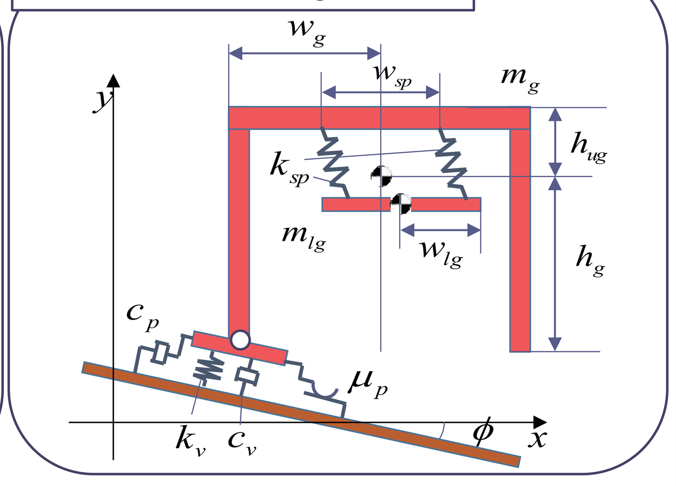
• The V. C. M. is omitted.

Models for simulation

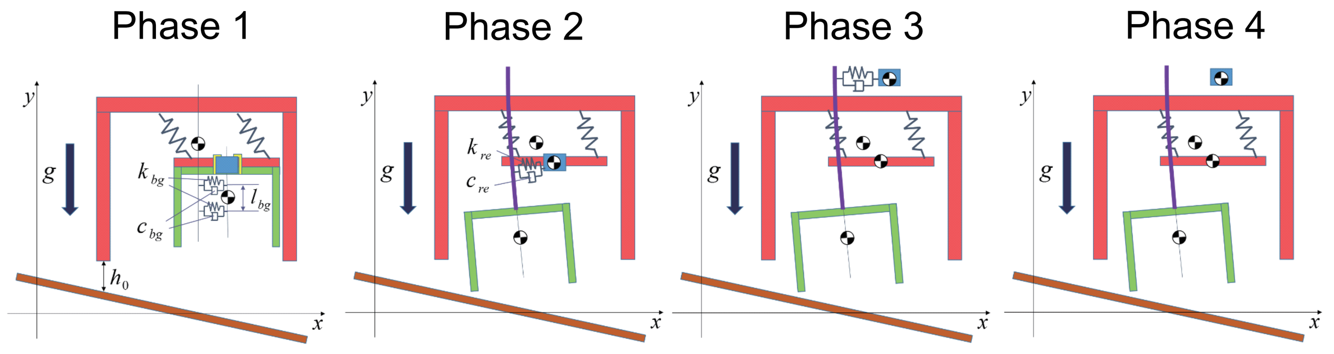
• Model for the base

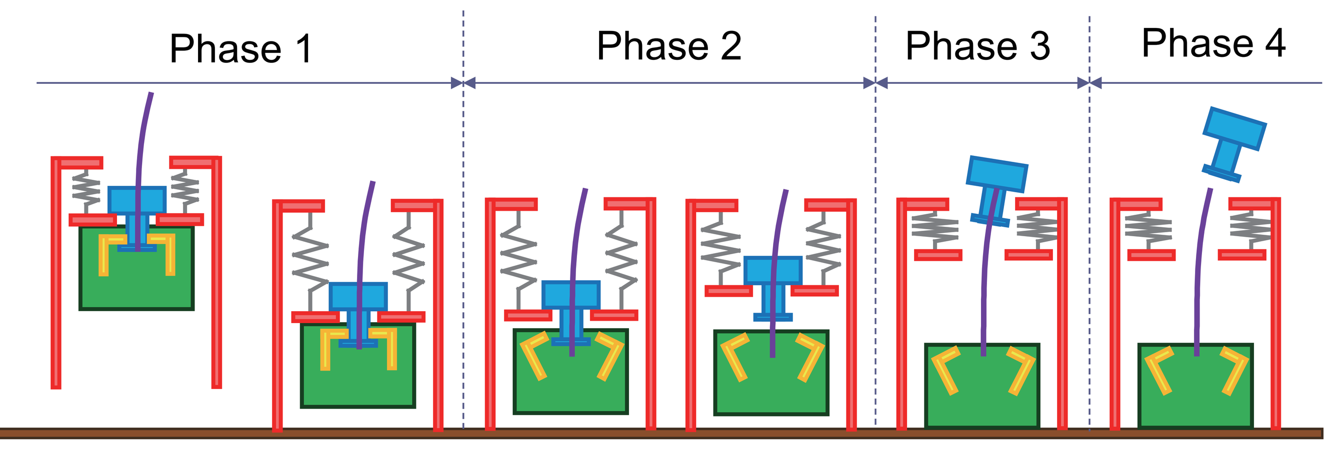


• Model for the gear

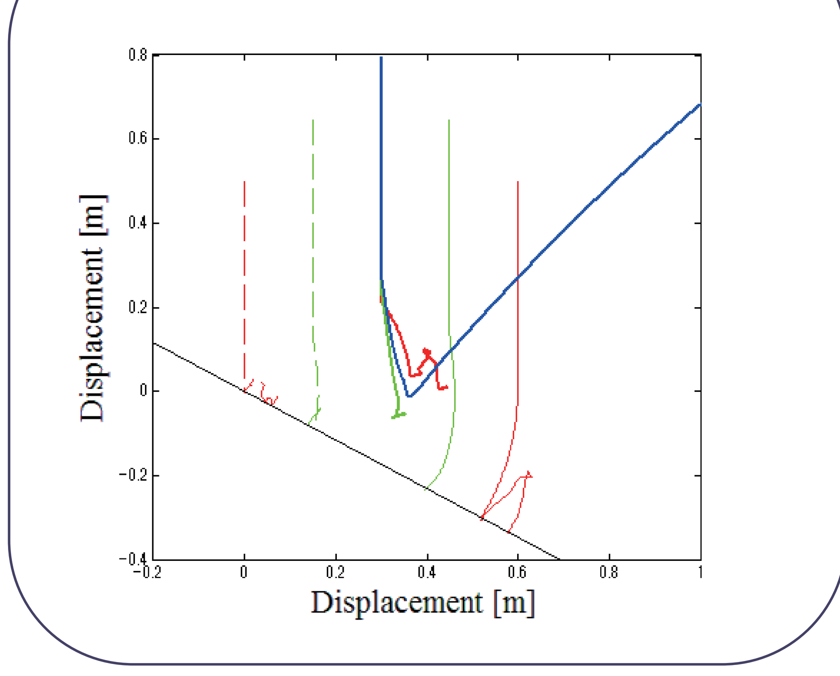


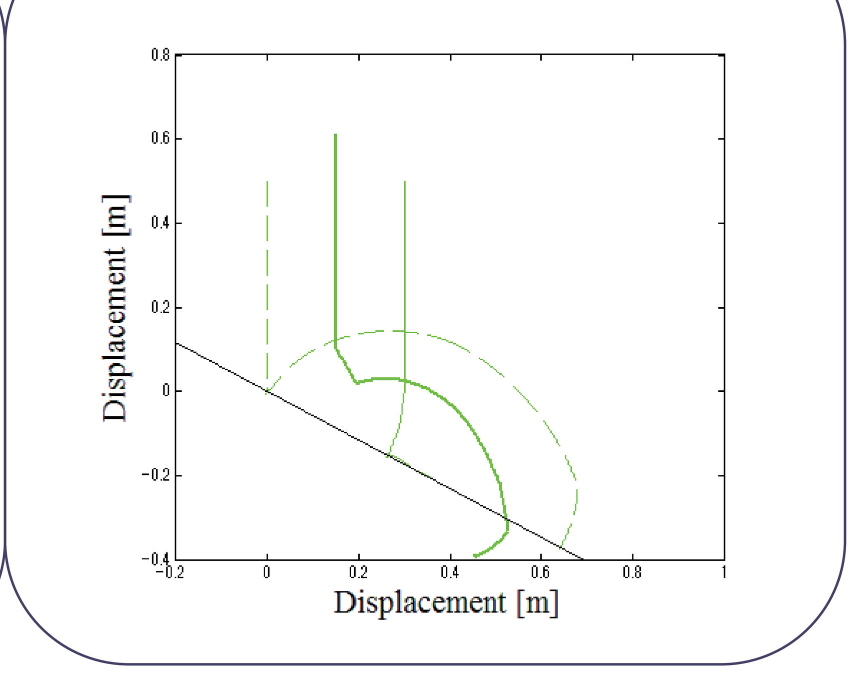
m_b	Base mass [kg]	1.9
m_e	Extension mass [kg]	0.1
w_b	Width of the base [m]	0.15
h_b	Base lower length [m]	0.11
h_{ub}	Base upper length [m]	0.04
m_g	Gear mass [kg]	0.4
w_g	Width of the gear [m]	0.3
h_g	Gear lower length [m]	0.216
h_{ug}	Gear upper length [m]	0.108
m_{lg}	Lower gear mass [kg]	0.05
w_{lg}	Width of the lower gear [m]	0.15
k_{sp}	Stiffness of springs [N/m]	220
w_{sp}	Width between springs [m]	0.15
l_{st}	Stroke length [m]	0.16
k_v	Vertical stiffness of ground [N/m]	1667
c_v	Vertical damping of ground [N・s/m]	556
c_p	Parallel damping of ground [N・s/m]	556
μ_p	Parallel dynamic coefficient of friction of ground [-]	0.8
ϕ	Ground angle [°]	-30
k_{bg}	Stiffness of the restriction between the base and gear [N/m]	1.0×10^4
c_{bg}	Damping of the restriction between the base and gear [N・s/m]	100
l_{bg}	length between the two couples of spring and damper [m]	0.08
k_{re}	Stiffness of the restriction between the extension and rail [N/m]	1.0×10^4
c_{re}	Damping of the restriction between the extension and rail [N・s/m]	100
h_0	Initial falling height [m]	0.5
g	Acceleration of gravity [m/s^2]	9.8





Simulation results



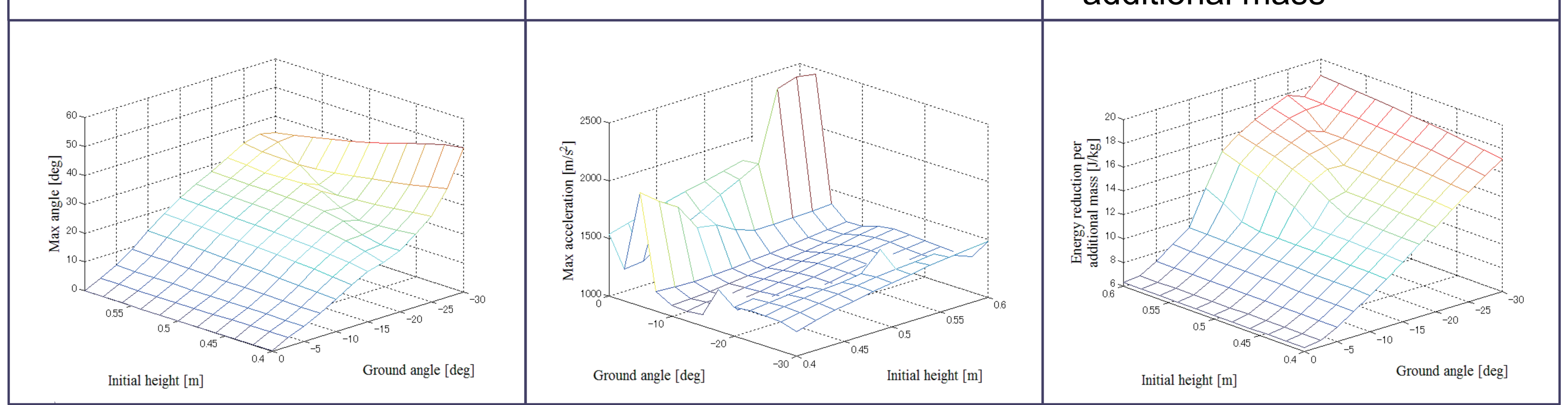


Red: gear Green: base Blue: extension
Bold: center of gravity Thin: right tip Dashed: left tip

- ● 30°の着地面への着陸において，親機の転倒を防ぐことができた．
- ☐ BESM can prevent from tipping for falling to 30° slope.

◆Ground angle and initial height change.

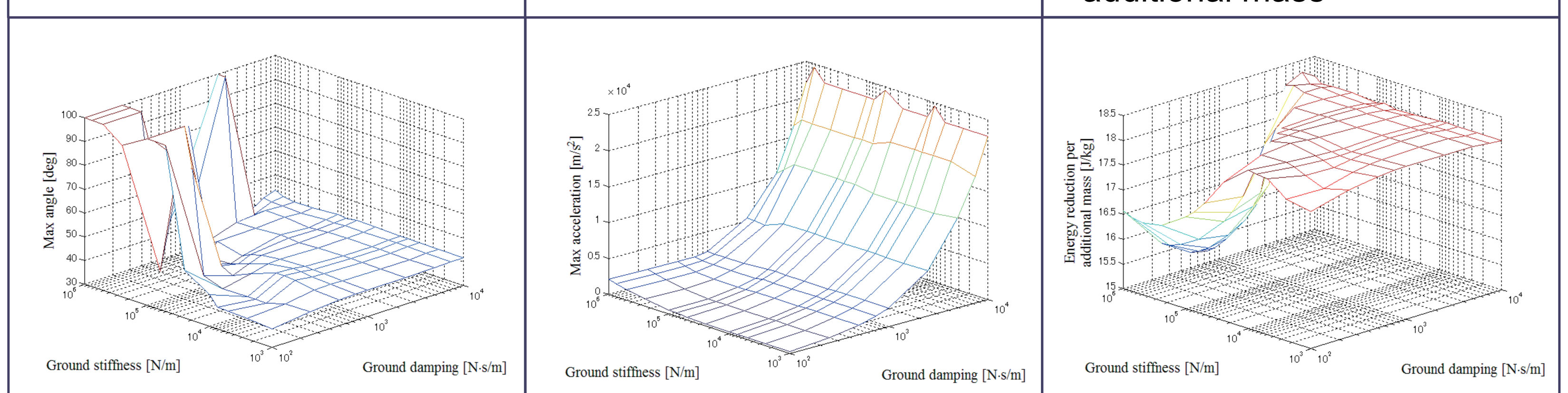
Max. angle of the base	Max. acceleration of the base	Base's energy reduction per additional mass



- ● 全ての条件で，親機の転倒を防ぐことができた．
- ☐ BESM can prevent from tipping under all conditions.
- ☐ Acceleration becomes high under small ground angle conditions.
- ☐ Energy reduction becomes large under large ground angle conditions.

◆Ground stiffness and ground damping change.

Max. angle of the base	Max. acceleration of the base	Base's energy reduction per additional mass



- ● 一部を除くほぼ全ての条件で，親機の転倒を防ぐことができた．
- ☐ BESM can prevent from tipping under most of conditions.
- ☐ Acceleration almost depends on only ground damping.
- ☐ Efficiency to prevent tipping may relate to efficiency of energy reduction.

Conclusion

- ☐ BESM has robustness for change of ground conditions and initial height.
- ☐ Efficiency to prevent from tipping may relate to efficiency of energy reduction.
- ☐ Acceleration of the base becomes high under conditions that ground angle is small.

References

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