惑星探査機着陸機構 — 発展型 GMEID の提案

Planetary Exploration Spacecraft Landing Gear System - Proposal of Advanced GMEID

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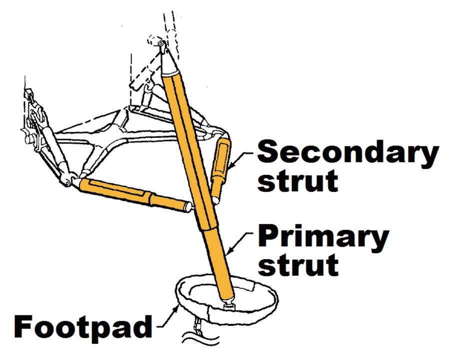
This paper discusses a planetary exploration spacecraft landing gear system on the basis of momentum exchange principles. The authors have already proposed the generalized momentum exchange impact damper (GMEID) that absorbs the controlled object’s momentum with the damper masses. This presentation shows an advanced version of the GMEID (G-Advanced). G-Advanced reduces the number of damper masses and maintains similar rebound reduction performance in comparison with GMEID. The characteristics of G-Advanced are investigated by simulations.

Background of the Study

Landing on all kinds of regions

⟶ **Undesirable shock response** may be happened.



Honeycomb crush (NASA)

Sky crane (NASA)

Landing gear must prevent shock response

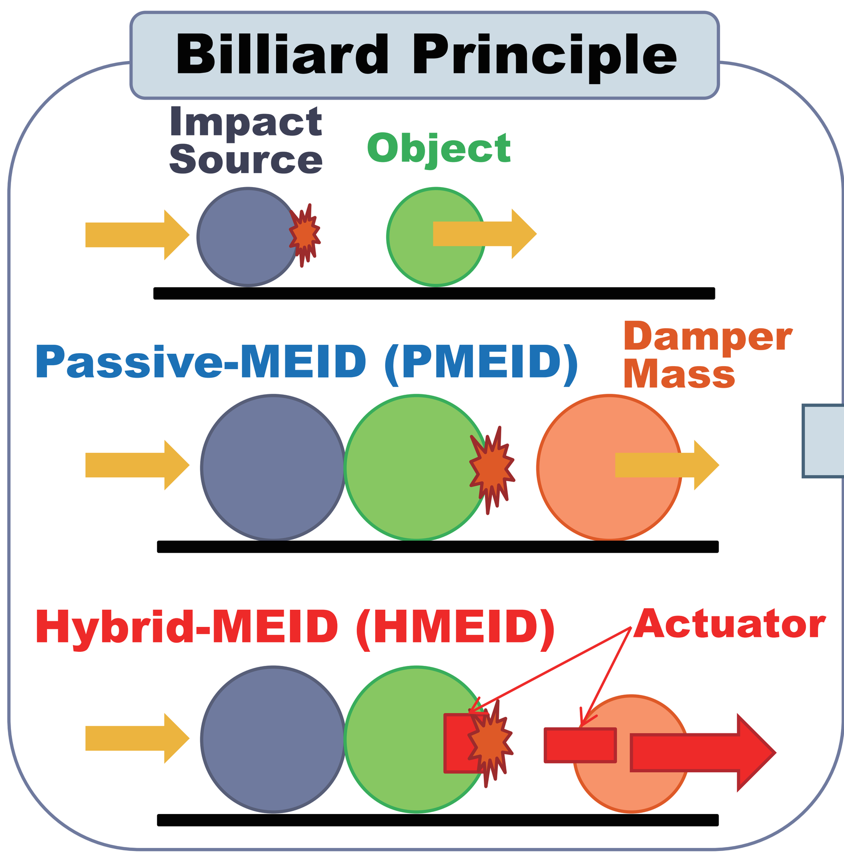
- **Honeycomb crush**[1]
  Can be used only once. — **Low reliability**, **High cost**
- **Sky crane**[2]
  High cost

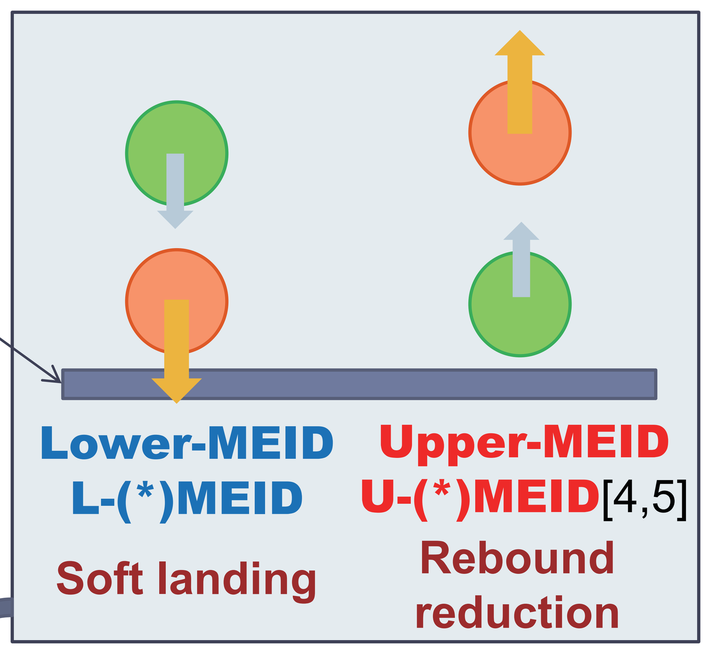
➡ **Landing gear with high reliability low cost is needed.**

MEID Mechanism

(Momentum Exchange Impact Damper : MEID)[3]

Transfer the controlled object’s momentum to the damper mass





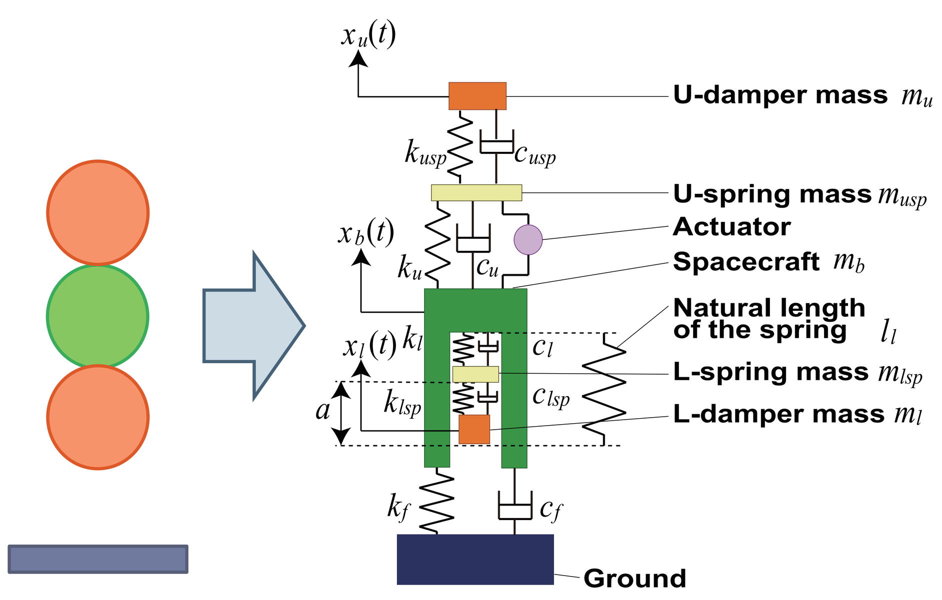
Generalized-MEID G-(*)MEID

Combine **L-MEID** and **U-MEID**

* P or H is filled in

Problems of G-MEID

G-MEID has two remaining problems.



Model with G-HMEID

Two damper masses are needed.

- Load mass must be **reduced**.

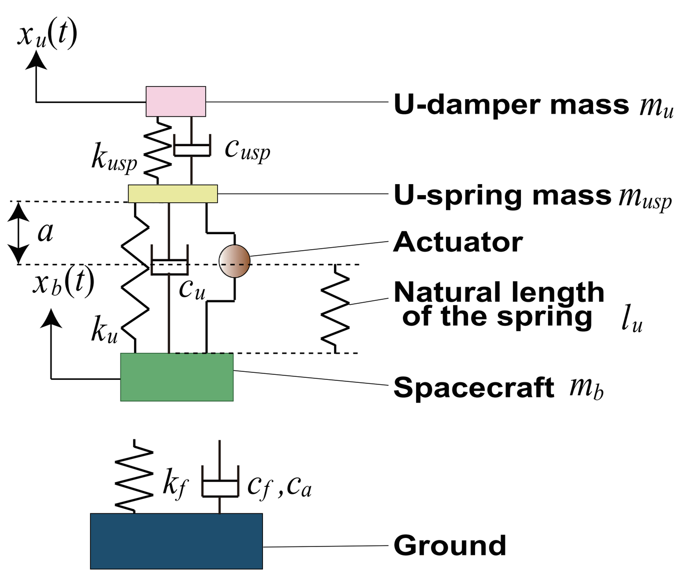
L-damper mass drops vigorously

- It may **disrupt** and **pollute** the landing site.
- It may **rebound** and **touch** with the spacecraft.

➡ **Improvement of G-MEID is needed.**

Introduction of Improved G-MEID

G-MEID-A (Generalized-MEID-Advanced)

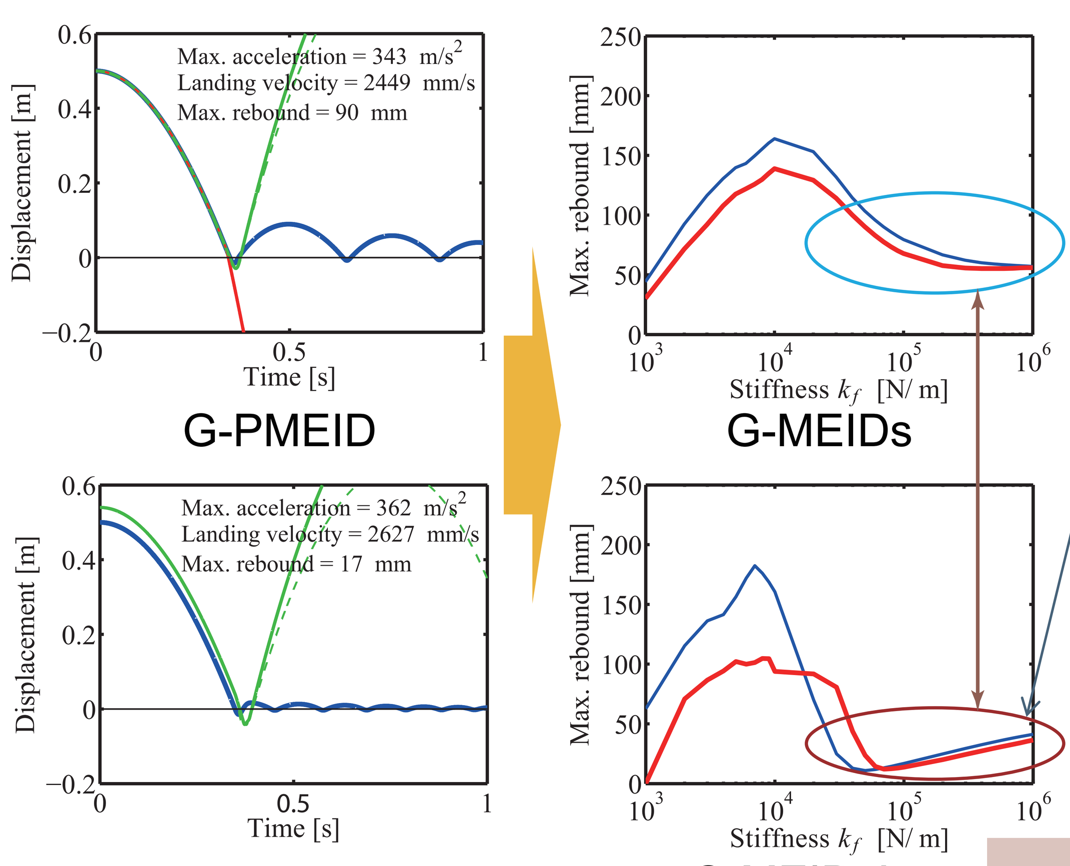


Model with GA-HMEID

Tense the U-spring in advance and open it just before landing.

- L-damper mass is **not need.**
  ⟶ **More equipment can be loaded.**
- **More effective rebound reduction** can be achieved.

G-MEID-A Simulation



G-PMEID　G-MEIDs

G-PMEID-A　G-MEID-As

Body mass
U-damper mass
L-damper mass

PMEID
HMEID

Ground Damping: $c_f = 40\,\mathrm{N{\cdot}s/m}$

High efficiency

- **G-HMEID-A** especially reduces the body’s rebound.
- G-MEID-A is **lighter** than G-MEID.
  5.64 kg ⟶ **4.95 kg**

G-HMEID-A has best performance of all the MEIDs.

Conclusion

MEIDs are applied to the spacecraft’s landing problems.
The problems of G-MEID are listed.

G-MEID-A mechanism is introduced.
Some simulation results show the effectiveness of G-MEID-A.

U-damper mass	m_u	0.69 kg
U-spring mass	m_{usp}	0.35 kg
L-damper mass	m_l	0.24 kg
L-spring mass	m_{lsp}	0.45 kg
Body mass	m_b	3.91 kg
Actuator maximum force		119 N
U-spring constant	k_u	20,000 N/m
L-spring constant	k_l	10,000 N/m
U-spring constant (G-MEID-A)	l_l	7,000 N/m
Initial compression amount of L-spring	a	0.020 m
Initial tension amount of U-spring	a	0.040 m
Initial height		0.50 m

References

[1] Rogers, W. F., Apollo Experience Report Lunar Module Landing Gear Subsystem, NASA TN D-6850, NASA, (1972), pp.6-21.

[2] NASA, ”Strange but True: Curiosity’s Sky Crane”. NASA SCIENCE - Home (online), available from <http://science.nasa.gov/science-news/science-at-nasa/2012/30jul_skycrane/>, (accessed 2012-11-29).

[3] Son, L., Hara, S., Yamada, K. and Matsuhisa, H., Experiment of Shock Vibration Control Using Active Momentum Exchange Impact Damper, *Journal of Vibration and Control*, Vol.16, No.1 (2010), pp.49-64.

[4] Hara, S., Ito, R., Otsuki, M., Yamada, Y., Kubota, T., Hashimoto, T., Matsuhisa, H. and Yamada, K., Momentum-Exchange-Impact-Damper-Based Shock Response Control for Planetary Exploration Spacecraft, *Journal of Guidance, Control, and Dynamics,* Vol.34, No.6, (2011), pp.1828-1838.

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