

Delft University of Technology

A Space Multi-Beam Multi-Link Capable Laser Communications Terminal for Satellites [PPT]

Spaander, Joshua; Guo, J.

Publication date 2021

Document Version Final published version

Citation (APA) Spaander, J., & Guo, J. (2021). A Space Multi-Beam Multi-Link Capable Laser Communications Terminal for Satellites [PPT].

Important note To cite this publication, please use the final published version (if applicable). Please check the document version above.

Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

Please contact us and provide details if you believe this document breaches copyrights. We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology. For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

Multi-Beam Terminal Design





By Joshua Spaander

Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2024 in (in zettabytes)





JDelft





























Ariane V Launch Costs:

- Cost for launch: \$165 million
- Launch capacity: 18,000 kg
- Cost per kg: 9,167 \$/kg



https://spacenews.com/arianespace-seeks-greater-support-from-european-governments/ https://www.yumpu.com/en/document/read/36996100/space-transportation-costs-trends-in-price-per-pound-to-orbit-

















Radio vs Optical Communications: 10 Mbps

- Radio:
 - Mass: 20.7 kg
 - Power: 104 W
- Optical:
 - Mass: 0.5 kg
 - Power: 10 W



	Lunar Laser Communications Demonstration (MIT LL)	Optical Payload for Lasercom Science (JPL)	Optical Communication and Sensor Demonstration (The Aerospace Corporation)	Nanosatellite Optical Downlink Experiment (MIT)
Data Rate	622 Mbps	50 Mbps	40 Mbps /300 Mbps	10 Mbps / 100 Mbps
Tx Power	0.5 W	2.5 W	6 W	200 mW
Orbit	Lunar	LEO (ISS)	LEO	LEO
Payload mass	30 kg	180 kg	2 kg	1 kg
Beamwidth	2.5 urad	~0.01 deg	0.30 deg	1.3 mrad
Ground station	White Sands	OCTL 1-m	MOCAM / MAFIOT	PorTeL / OCTL

ŤUDelft

	Lunar Laser Communications Demonstration (MIT LL)	Optical Payload for Lasercom Science (JPL)	Optical Communication and Sensor Demonstratio (The Aerospace Corporation)	Nanosatellite Optical Downlink Experiment (MIT)
Data Rate	622 Mbps	50 Mbps	40 Mbps /300 Mbps	10 Mbps / 100 Mbps
Tx Power	0.5 W	2.5 W	6 W	200 mW
Orbit	Lunar	LEO (ISS)	LEO	LEO
Payload mass	30 kg	180 kg	2 kg	1 kg
Beamwidth	2.5 urad	~0.01 deg	0.30 deg	1.3 mrad
Ground station	White Sands	OCTL 1-m	MOCAM / MAFIOT	PorTeL / OCTL

ŤUDelft





























Goal:

Combine all the laser links into one Size, Weight and Power (SWaP) friendlier package.

Using off the shelf components and implementing some improvements





List of design goals:

- Closed feedback loop
- Multi-beam steering mechanism
- Shared components between all beams
- No required beacon
- Handle 2-way (duplex) communications
- Designed using only Commercial Of The Shelf (COTS) parts
- Make the SWaP per link similar to that of systems such as NODE



Trade-off Steering Orientation







Incoming Beam Direction

Incoming Beam Direction





Configuration	Incoming Beam Steering	Outgoing Beam Steering
Feasibility	Feasable	Feasable
Splitter Complexity	Low	High
Steering Complexity	Low	High
Number of Spots Tracked	High	Low



JDelft

Differences between same-path and multi-path methods. • (Incoming = Red Outgoing = Blue)





Same-Path

Multi-Path

Criteria	Single Path 2 Steering Stages	Dual Path 1 Steering Stage	Weights
Feedback Complexity	1	0	4
Number of Components	0	1	2
Design Flexibility	1	0	4
Number of Beams To Track	1	0	4
Maximum Number of Steerable Beams	1	0	4
Mass	0	1	3
Power	0	1	1
Singal Power Efficiency	0	1	5
Total	16	11	27





2 steering systems also allows for combining the best of both worlds of MMA's and SLM's.

This makes the speed of the system more than sufficient.

Criteria	MMA	SLM	Weight Stage 1	Weight Stage 2
Speed	>300 Hz	<200 Hz & >60 Hz	1	1
Resolution	~10 x 10	>1920 x 1080	2	0
Weighted Total Stage 1	1	2		
Weighted Total Stage 2	1	0		



 10x10 MMA's are 10 times smaller than FSM's and almost as fast.





• SLM's (Spatial Light Modulators) where chosen because of their high resolutions.





HOLOEYE. Spatial Light Modulators



2 steering systems also allows for combining the best of both worlds of MMA's and SLM's.

This makes the speed of the system more than sufficient.

Criteria	MMA	SLM	Weight Stage 1	Weight Stage 2
C peeu	>300 Hz	<200 Hz & >60 Hz	1	1
Resolution	~10 x 10	>1920 x 1080	2	0
Veighted rotal Stage 1	1	2		
Weighted Total Stage 2	1	0		



High resolution vs low resolution steering





High resolution vs low resolution steering





High resolution vs low resolution steering

Beam steering algorithm: Results for MEMS MMA 10x10

Partial reflection of the beam by a pixel leads to half and quarter pixel diffractions. These decrease the received signal. This problem gets larger for larger beam widths.



This results in diffraction losses

High resolution vs low resolution steering





Higher resolutions have less issues with diffraction losses



2 steering systems also allows for combining the best of both worlds of MMA's and SLM's.

This makes the speed of the system more than sufficient.

Criteria	MMA	SLM	Weight Stage 1	Weight Stage 2
Speed	>300 Hz	<200 Hz & >60 Hz	1	1
Resolution	~10 x 10	>1920 x 1080	2	0
Weighted Total Stage 1	1	2		
Weighted Total Stage 2	1	0		





The use of the same-path approach implies very highperformance COTS fiber hardware can be used.















Modeling and Simulations

















Pointing Error Over Time Logarithmic with 5 Frame Moving Average



Simulation Frame/Time



Pointing Error Over Time Logarithmic with 5 Frame Moving Average



Simulation Frame/Time

105























Pointing Error Over Time Logarithmic with 5 Frame Moving Average



ŤUDelft

Pointing Error Over Time Logarithmic with 5 Frame Moving Average





11% of the time spots where crossing

Pointing Error Over Time Logarithmic with 5 Frame Moving Average





Thank you!

.

TUDelft

.

117