

NASA Centennial Challenges: A Comparison of the Flagsuit 2007 and 2009 Gloves with NASA EMU Glove, and Further Developments

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NASA's Centennial Challenges were created in 2005 to engage the public in developing advanced technology solutions, offering cash incentive prizes to spur innovation from diverse and non-traditional sources. The Astronaut Glove Challenge, held in 2007 and 2009, was one such event aimed at improving spacesuit gloves to enhance astronaut performance during space missions. Traditional spacesuit gloves posed significant issues for astronauts, including limited range of motion, resistance to bending at the joints, and lack of finger dexterity, which often lead to user hand and finger trauma. The challenge sought to address these problems by focusing on designs that reduced the effort needed to perform tasks in space while maintaining strength and flexibility.

Competitors in both the 2007 and 2009 Astronaut Glove Challenges demonstrated their designs for durability, flexibility, and leak prevention. The 2007 challenge required participants to submit only the pressure-restraining layer(s), while the 2009 challenge raised the bar by requiring a complete glove, including the outer thermal-micrometeoroid-protection layer in addition to the pressure-restraining layer(s).

Flagsuit stood out in both years, outperforming all other teams as well as NASA's own EMU Phase VI glove. In 2007, five teams registered, including Flagsuit and Team MDLH--which featured a strong lineup of space suit experts, Gary Harris, Pablo de Leon, and Nik Moiseev--along with individual competitors like Ted Southern. Teams initially passed acceptance testing, including evaluations of glove length, weight, and leak checks. Competition scoring was based on three factors: glove strength, joint flexibility, and comfort/dexterity.

The strength of the gloves was tested through a burst test, where each competitor pressurized a glove until it failed. Flagsuit's glove reached nearly 22 psi before failure, while Team MDLH's glove survived up to 29 psi, both exceeding the 13 psi qualifying minimum. In the 2007 competition, other competitors' gloves did not pass this test.

Flexibility measurements involved subjective assessments using a force gauge, with repeated testing to ensure consistent results. In this test, a combined score (all finger, thumb and wrist joints) was determined for each entry. A lower combined score represents lower bending resistance thus improved flexibility and dexterity. Flagsuit excelled here as well, achieving lower finger-bending torques than NASA's Phase VI glove, showcasing its superior flexibility and comfort.

Lastly, in a vacuum glove box, competitors performed a set of finger, thumb, and wrist motions to assess dexterity and comfort, ensuring no signs of abrasion or bruising. All competitors passed this test.

In both 2007 and 2009 competitions, the Flagsuit gloves took first place, demonstrating a significant improvement over existing spacesuit glove technology and setting a new standard for astronaut glove design. Flagsuit's success is attributed to its "linkage" design across the joint of the finger using a material restraint in the shape of an "X" that allowed a user to make a fist without feeling any resistance. The same "X" design is applied for thumb articulation, and wrist joints.

The data and photos below are from the 2007 and 2009 NASA Centennial Challenges. Flagsuit continued development and refinement of glove joint flexibility under contract to NASA. The Flagsuit Improved Glove was tested in 2011 using the same methodology and scoring as the

Astronaut Glove Centennial Challenge and the results are presented for comparison. Flagsuit maintains design patents as well as provisionals on its designs.

Glove Bending Torque Comparison

Showing progress in achieving lower bending torques / higher operating pressures

	NASA EMU Phase VI	Flagsuit 2007 Centennial Challenge	Flagsuit 2009 Centennial Challenge	Flagsuit 2011 Improved Glove
Pressure (psid)	4.3	4.3	4.3	8.3
COMBINED SCORE*	58.99	58.31	24.66	55.02
Stiffness relative to NASA EMU at 4.3 psid	100.0%	98.9%	41.8%	93.3%

(*Scores computed using scoring methodology of NASA Astronaut Glove Centennial Challenges)

NASA EMU Phase VI

Glove test without TMG

4.3 psid		Spec. Bending Range from Neutral Position (deg)	Measured Force (lb)	X	Measured Distance to Break Point (in)	=	Joint Torque (in-lb)	Average for Each Grouping (in-lb)
Group 1	Wrist Flexion	30	6.0	X	4.0	=	24.00	21.00
	Wrist Extension	30	4.5	X	4.0	=	18.00	
Group 2	Wrist Abduction	45	6.5	X	5.7	=	37.05	35.75
	Wrist Adduction	45	6.5	X	5.3	=	34.45	
Group 3	Pinky Flexion	90	0.5	X	1.4	=	0.70	0.88
	Ring Flexion	90	0.6	X	1.6	=	0.96	
	Middle Flexion	90	0.6	X	1.7	=	1.02	
	Index Flexion	90	0.6	X	1.4	=	0.84	
Group 4	Thumb Flexion	90	0.8	X	1.7	=	1.36	1.36

Joint Torque Score = Sum of Scores for Each Group

58.99

Data from: 2009 NASA Astronaut Glove Centennial Challenge

Flagsuit 2007 Centennial Challenge

Glove test without TMG

4.3 psid		Spec. Bending Range from Neutral Position (deg)	Measured Force (lb)	X	Measured Distance to Break Point (in)	=	Joint Torque (in-lb)	Average for Each Grouping (in-lb)
Group 1	Wrist Flexion	45	6.0	X	4.0	=	24.00	21.00
	Wrist Extension	45	4.5	X	4.0	=	18.00	
Group 2	Wrist Abduction	30	6.5	X	5.7	=	37.05	35.75
	Wrist Adduction	30	6.5	X	5.3	=	34.45	
Group 3	Pinky Flexion	45-75	0.5	X	0.9	=	0.42	0.52
	Ring Flexion	45-75	0.5	X	0.9	=	0.46	
	Middle Flexion	45-75	0.6	X	1.0	=	0.56	
	Index Flexion	45-75	0.8	X	0.9	=	0.66	
Group 4	Thumb Flexion	45-75	0.9	X	1.2	=	1.04	1.04

Joint Torque Score = Sum of Scores for Each Group

58.31

Data from: 2007 NASA Astronaut Glove Centennial Challenge

Flagsuit 2009 Centennial Challenge

Glove test without TMG

4.3 psid		Spec. Bending Range from Neutral Position (deg)	Measured Force (lb)	X	Measured Distance to Break Point (in)	=	Joint Torque (in-lb)	Average for Each Grouping (in-lb)
Group 1	Wrist Flexion	30	3.0	X	2.9	=	8.70	9.25
	Wrist Extension	30	3.5	X	2.8	=	9.80	
Group 2	Wrist Abduction	45	2.5	X	5.2	=	13.00	12.98
	Wrist Adduction	45	2.7	X	4.8	=	12.96	
Group 3	Pinky Flexion	90	0.7	X	1.1	=	0.77	0.99
	Ring Flexion	90	0.6	X	1.6	=	0.96	
	Middle Flexion	90	0.7	X	1.7	=	1.19	
	Index Flexion	90	0.7	X	1.5	=	1.05	
Group 4	Thumb Flexion	90	0.8	X	1.8	=	1.44	1.44

Joint Torque Score = Sum of Scores for Each Group

24.66

Data from: 2009 NASA Astronaut Glove Centennial Challenge

Flagsuit 2011 Improved Glove

Glove test without TMG

8.3 psid		Spec. Bending Range from Neutral Position (deg)	Measured Force (lb)	X	Measured Distance to Break Point (in)	=	Joint Torque (in-lb)	Average for Each Grouping (in-lb)
Group 1	Wrist Flexion	50		X		=	39.05	36.89
	Wrist Extension	40		X		=	34.73	
Group 2	Wrist Abduction	15		X		=	12.75	15.70
	Wrist Adduction	15		X		=	18.65	
Group 3	Pinky Flexion	90	0.7	X	1.1	=	0.77	0.99
	Ring Flexion	90	0.6	X	1.6	=	0.96	
	Middle Flexion	90	0.7	X	1.7	=	1.19	
	Index Flexion	90	0.7	X	1.5	=	1.05	
Group 4	Thumb Flexion	90	0.8	X	1.8	=	1.44	1.44

Joint Torque Score = Sum of Scores for Each Group

55.02

Data from: 2011 Verification Test Data, contract NNJ11HA36P

Finger torque data not measured. Used 2009 Centennial Challenge torque data for comparison.



Figure 1 Astronaut Glove Challenge (2009) – Challenge winner Peter Homer observes Johnson Space Center’s Spacesuit Designer, Amy Ross, as she tests his astronaut glove prototype in a vacuum chamber. Image credit NASA



Figure 2 Astronaut Glove Challenge (2009) – An advanced astronaut glove prototype is tested in a vacuum chamber at Johnson Space Center in Houston, Texas. Its wearer, Peter Homer, won the challenge in both 2007 and 2009 image credit NASA

Additional References:

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