NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER

JUSTIFICATION FOR AN EXCEPTION TO THE FAIR OPPORTUNITY PROCESS REFERENCE FEDERAL ACQUISITION REGULATION 16.505(b)(2)(ii)

1. This document is a Justification for an Exception to the Fair Opportunity (JEFO) Process prepared by the NASA Lyndon B. Johnson Space Center (JSC) for Crew, Robotics, Avionics, & Vehicle Equipment (CRAVE).

2. The nature and/or description of the action being approved:

JSC is proposing to contract through the CRAVE II – Indefinite-Delivery/Indefinite-Quantity (IDIQ) Delivery Order (DO) 2 with Oceaneering Space Systems, Inc. (OSS) for the Advanced Robonaut Hardware to acquire additional Robonaut Hardware and Software from OSS. The current cost-plus-fixed-fee value of this DO is $10,786,231.

OSS is the only awardee capable of providing the supplies and services required at the level of quality required because the supplies or services ordered are unique or highly specialized as illustrated in shared patents.

3. Description of the supplies or services required, include an estimated value:

The supplies required include fabric coverings for Robonaut derived exoskeleton and robotic systems. The services include control software testing with test-beds and exoskeleton hardware. This DO will also include software deliveries for Robonaut handrail obstacle avoidance software, handrail localization software, and obstacle detection and localization software.

The estimated value for this effort is $1,600,000.

4. The authority and supporting rationale and, if applicable, a demonstration of the proposed contractor's unique qualifications to provide the required supply or service:

As demonstrated below in Section 6, OSS has unique qualifications and holds many joint patents on this technology that make them the only responsible source capable of performing this effort within the required timeframe. The statutory exception to the fair opportunity process is made pursuant to FAR 16.505(b)(2)(i)(B), "Only one awardee is capable of providing the supplies or services required at the level of quality required because the supplies or services ordered are unique or highly specialized."

Engineering hardware development and rapid prototyping activities for the Robonaut R2 are critical for completing additional Robonaut functions and functional testing of hardware to prove out mobility and demonstration of inspection/maintenance tasks. The R2 effort is funded by Space Technology Mission Directorate to further robotic capabilities to augment its mobility in

the Intra-vehicular Activity (IVA) environment. Lessons learned from that activity will be applied to the Extra-Vehicular Activity (EVA) – Robotics.
OSS has extensive experience with the R2 design of the power systems, fabrics, avionics, software, human interface, and mechanisms that are implemented. Transferring this qualitative experience to other similarly qualified designers and technicians would be cost prohibitive.

All of the Robonaut's fabric coverings and instrumented gloves were designed in collaboration with OSS personnel. They were built and tested by OSS personnel. Robonaut's current configuration (R2) was built, integrated, and tested by OSS personnel. Robonaut's firmware system, which controls motor power at a joint level, was designed by OSS as part of a contract between NASA and OSS.

The current Robonaut leads include OSS personnel in the following technical areas:

a) Soft Goods
b) Leg Subsystem
c) Machine vision software
d) Battery assembly and test
e) Upper-body Assembly
f) Task/Procedure Development
g) Mechanical Design and Test
h) Exoskeleton design

OSS has extensive experience with NASA on the Robonaut and exoskeleton designs and hold patents jointly with NASA and General Motors (GM) on the Robonaut design.

Under NASA contractual processes (CRAVE I & II), OSS successfully designed, fabricated, and tested multiple subsystems for the Robonaut R2 units from 2010-2014.

5. Determination by the Contracting Officer (CO) that the order will be fair and reasonable:

This revision will utilize existing rates in the CRAVE II contract. These rates have already been determined to be fair and reasonable; prior to the award of the proposed order, cost information will be obtained from OSS and a cost analysis will be performed and documented to sufficiently determine that the order represents the best value and results in the lowest overall cost alternative to meet the Government's needs. The labor hours and skill mix will be evaluated and approved by the Contracting Officer's Representative with inputs from the DO Manager.

6. Other facts supporting the use of exceptions to the fair opportunity process:

The following list denotes the patents held jointly by GM, NASA, and OSS for Robonaut Items:

NO.	Title	Filing Number	Filing Date
1	JOINT-SPACE IMPEDANCE CONTROL FOR TENDON-DRIVEN MANIPULATORS	12/335153	15 Dec 2008
2	ARCHITECTURE FOR ROBUST FORCE AND IMPEDANCE CONTROL OF SERIES ELASTIC ACTUATORS	12/698832	02 Feb 2010
3	MULTIPLE PRIORITY OPERATIONAL SPACE IMPEDANCE CONTROL	12/338697	18 Dec 2008
4	PLANAR TORSION SPRING	12/331844	10 Dec 2008
5	METHOD AND APPARATUS FOR ELECTROMAGNETICALLY BRAKING A MOTOR	12/474430	29 May 2009
6	CONTACT STATE ESTIMATION FOR MULTI-FINGER ROBOT HANDS USING PARTICLE FILTERS	12/474068	28 May 2009
7	DEXTEROUS HUMANOID ROBOTIC WRIST	12/564088	22 Sep 2009
8	ROBOTIC FINGER ASSEMBLY	12/564078	22 Sep 2009
9	TENDON DRIVEN FINGER ACTUATION SYSTEM	12/564086	22 Sep 2009
10	INTEGRATED HIGH-SPEED TORQUE CONTROL SYSTEM FOR A ROBOTIC JOINT	12/564076	22 Sep 2009
11	SYSTEM AND METHOD FOR CALIBRATING A ROTARY ABSOLUTE POSITION SENSOR	12/564092	22 Sep 2009
12	ROTARY SERIES ELASTIC ACTUATOR	12/564090	22 Sep 2009
13	ROBOT	29/359105	06 Apr 2010
14	ACTUATOR AND ELECTRONICS PACKAGING FOR EXTRINSIC HUMANOID HAND	12/564124	22 Sep 2009
15	FRAMEWORK AND METHOD FOR CONTROLLING A ROBOTIC SYSTEM USING A DISTRIBUTED COMPUTER NETWORK	12/564094	22 Sep 2009
16	HUMANOID ROBOT	12/564084	22 Sep 2009
17	APPLYING WORKSPACE LIMITATIONS IN A VELOCITY-CONTROLLED ROBOTIC MECHANISM	12/787479	26 May 2010
18	METHOD AND SYSTEM FOR CONTROLLING A DEXTEROUS ROBOT EXECUTION SEQUENCE USING STATE CLASSIFICATION	13/196252	02 Aug 2011
19	WORKSPACE SAFE OPERATION OF A FORCE-OR IMPEDANCE-CONTROLLED ROBOT	12/875254	03 Sep 2010

20	ROBUST OPERATION OF TENDON-DRIVEN ROBOT FINGERS USING FORCE AND POSITION-BASED CONTROL LAWS	12/916803	01 Nov 2010
21	FAST GRASP CONTACT COMPUTATION FOR A SERIAL ROBOT	13/207911	11 Aug 2011
22	HUMAN GRASP ASSIST SOFT	13/408668	29 Feb 2012

OSS is part of Oceaneering International, Inc.

OSS's unique expertise as illustrated by the patents identified is critical to the successful design and fabrication of the Robonaut R2 that is needed for the Robonaut to International Space Station (ISS) project. Their historical knowledge built over 19 years of developing this technology is crucial for continued successful development of the Advanced Robonaut Hardware.

OSS has crucial knowledge of fabric coverings and their IVA/EVA suitability, and avionics including the embedded electronics and control systems. The mechanism skills from OSS are critical for dexterous robotics systems (arm and hand) and the leg subsystem and its characteristics. In order to reach this level of competency, another contractor would be required to duplicate many of the internal and contracted research and development efforts and costs already incurred by the Government and OSS. Without this knowledge, a new vendor would be unable to quickly develop a Robonaut R2 design and prototyping legs. If this effort is not initiated with OSS, the Robonaut to ISS project will not meet its overall objectives to provide NASA with robotic test-bed technologies to enable future missions.

7. A statement of the actions, if any, the Agency may take to remove or overcome any barriers that led to the exception to fair opportunity before any subsequent acquisition for the supplies or services is made:

The Government is unable to remove or overcome any barriers to competition as long as we use this NASA/GM/OSS design that utilizes the extensive skills, experience and techniques that OSS has acquired over the last 19 years. Transferring of these critical skills and experience would be cost prohibitive. Also, the details of the patents cannot be shared without divulging proprietary data.

8. Evidence that any supporting data that is the responsibility of technical or requirements personnel (e.g., verifying the Government's minimum needs or requirements or other rationale for an exception to fair opportunity) and which form a basis for the justification have been certified as complete and accurate by the technical or requirements personnel:

The Government has reviewed the technical requirements within the NASA JSC Engineering Directorate's Software, Robotics, and Simulation Division and with other Governmental organizations such as ISS and Office of Chief Technology. They are complete and accurate as

determined by the technical community. The technical requirements are contained in the technical requirements document.

Additional information supporting the justification illustrates the various contracting mechanisms used for Dexterous Robotic Development including Robonaut – R2:

Item	Contract	Date
1	Direct contract to OSS	1996-1999
2	Subcontract to OSS through Science, Engineering, Analysis, and Test (Lockheed) contract	2000-2005
3	Subcontract to OSS through Engineering and Science Contract (Jacobs) contract	2005-2007
4	Direct contract to OSS through CRAVE I contract	2007-2010
5	Direct contract to OSS through CRAVE II contract	2010-Present

During these 19 years of performance, OSS has made unique contributions to the successful development of the Robonaut systems. Shown in the following table, these contributions have spanned the development of the major advances in fabric coverings, miniature embedded avionics, and the testing of the robots in chambers and remote field sites. This table represents decades of work and unique corporate knowledge that distinguishes OSS from all other possible bidders on the work.

Item	Description of OSS prior Robonaut work	Date
1	Five generations of glove fabric covering design and manufacturing	1998-2005
2	Three generations of arm fabric covering design and manufacturing	2001-2006
3	Two generations of embedded motor drivers for miniaturized arm joints	1996-2007
4	Finger sensor design, analysis and calibration	1996-2007
5	Finger motor driver design, analysis and testing	1996-1998
6	Wrist actuator design, analysis and manufacturing	1997-1999
7	Power management and control system	2002-2007
8	Arm joint torque sensor design and manufacturing	1997-2002
9	Arm and hand thermal management system design and analysis	2004-2006
10	Field Programmable Gate Array Design for motor control	1996-2007
11	Safety system design and implementation	2004-2007
12	Wireless video subsystem design and implementation	2003-2007
13	Battery subsystem design, manufacturing and testing	2006-2007
14	Tactile sensor design interface design and fabrication	2002-2007
15	Fabrication of Robonaut 1C arm joints and Thermal Vacuum Chamber jigs	2006-2007
16	OSS completed audit or Robonaut technology for space worthiness	2006-2007
17	OSS directed the Electromagnetic Interference chamber testing of Robonaut 1B technology	2006-2007
18	Lead field deployment test for Robonaut off site testing	2004-2007
19	Design of dust protection for Robonauts on planetary environments	2006-2007

20	Updated the power subsystem for Robonaut R2 design including power interface schematics	2007-2010
21	Updated the fabric requirements and design for Robonaut R2 design	2007-2010
22	Updated the joint mechanism design (including custom links, drive trains, and interfaces) for Robonaut R2 design	2007-2010
23	Updated Control Software and testing for Robonaut R2 design	2007-2010
24	Updated embedded joint avionics and testing for Robonaut R2 design	2007-2010
25	Updated body design to accommodate attachment of legs to R2 design	2010-Present
26	Design fabric coverings for exoskeleton including the legs	2010-Present
27	Update the robot control software to reduce friction effects and improve Cartesian Bandwidth	2010-Present
28	Design vision software to identify task board and maintenance boxes and conduct testing	2010-Present
29	Design leg mechanisms that will be integrated with R2 upper body design and conduct Thermal Vacuum Chamber testing	2010-Present
30	Design fixtures for environmental testing and conduct testing of leg subsystem	2010-Present
31	Design exoskeleton mechanisms and embedded avionics for the R2 architecture	2010-Present
32	Plan Robot Task development and implement vision calibration. Conduct testing using hand held tools.	2010-Present
33	Conduct climbing/walking design and analysis	2010-Present