Area di Ricerca del CNR
Istituto Nazionale di Astrofisica
Radio Astronomia

Bologna, 18 e 19 Maggio 2018

SRITAC 2 - 2018 - Officine orbitali, primo livello di espansione civile nello spazio

Technologies for the construction of space infrastructures

DR. STEFANO FERRETTI

OUTLINE

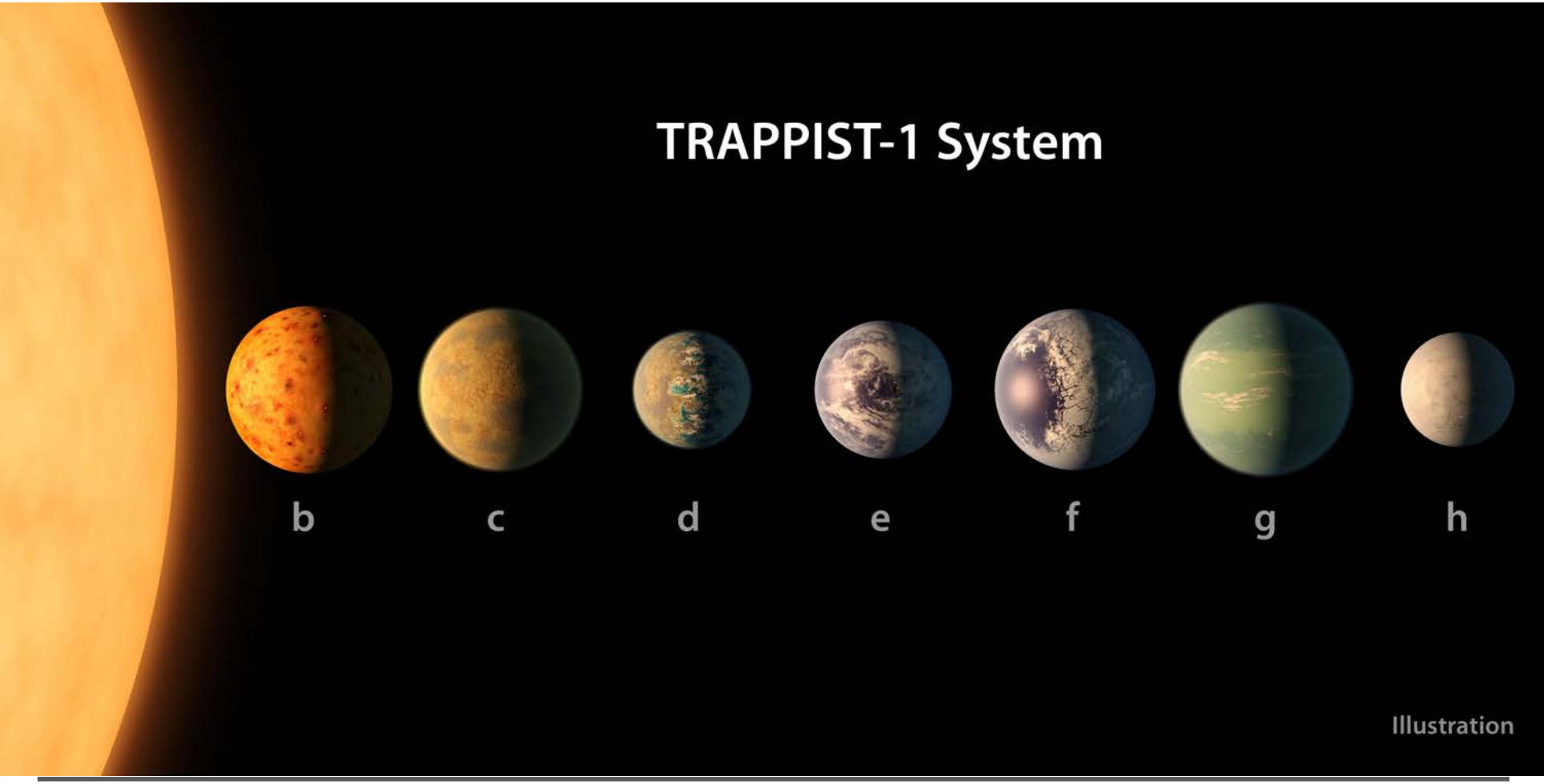
- Space Exploration
- Where are we now ?
- What are the opportunities ?
- Building in Space
- Living and Working in Space
- A global vision

EXPLORING AROUND AND ABOVE …

What's new?

- UN AGENDA 2030 & COP21: EARTH CALL
- NASA SLS AND SPACE-X: TRAVELS TO MARS
- EUROPEAN UNION SPACE STRATEGY: BENEFITTING THE CITIZENS
- ESA UNITED SPACE IN EUROPE, SPACE 4.0 AND MOON VILLAGE: NEW VISION FOR OLD EUROPE
- CHINESE SPACE STATION: A NEW LEO PERSPECTIVE
- UNISPACE +50: FOUR PILLARS FOR HUMANITY

WHERE ?



HOW ?

- New Space entrepreneurs and human expansion in Space
  - Elon Musk: multiplanetary species?
  - Jeff Bezos: 1 trillion people in space ?
  - New ideas, new paradigms: a vision or a dream ?

Earth is the cradle of humanity, but one cannot remain in the cradle forever.
Konstantin Tsiolkovsky

WHERE ARE WE NOW ?

- Humans have explored Earth surroundings
  - Short duration missions in LEO (Russia, USA, China)
- Landed on the Moon and returned safely on Earth
  - Apollo missions with Saturn V
  - New NASA SLS next year
- Permanently lived and worked in Space
  - On board ISS (6 months increments, max 7 people)

WHAT ARE THE CHALLENGES ?

- Space environment
  - micrometorites, space debris, radiations, thermal stresses
- Long duration space flights
  - Earth Orbit and Space Stations
    - ☞ Maintenance
  - Moon and Mars manned exploration missions
    - ☞ Reusable Launch Vehicles
    - ☞ Planetary bases construction

WHAT ARE THE CHALLENGES ?

- Logistics
  - Upload costs (how much it will change ?)
- Astronaut health
  - 0 gravity environment and radiation
- On-orbit infrastructure
  - MAIT on Earth and transported in Space
  - Limited maintenance / spare parts reflight
  - End-of-life / de-orbiting

SPACE STATIONS

- Modular Space Habitats
  - Size/volume
  - ISS module limited by Shuttle cargo bay
  - Inflatable modules
- Artificial gravity (large rotating structures)
- Space tourism (new infrastructures develop)

PLANETARY SETTLEMENTS

- Data and tests
  - Simulation bases on Earth, underwater settlements
- Exploration bases
  - Structures, communications, vehicles
- Research facilities
  - biotech labs, agriculture greenhouses, etc
- Production plants (resources exploitation)
  - metal structures, tanks, pipelines, machines

SPACE DEBRIS: AN UNAVOIDABLE BARRIER ?

WHAT ARE THE OPPORTUNITIES ?

- Valuable assets in Space
  - De-orbiting: a cost and value loss
  - Circular Space economy ? Reuse !
  - Lessons learned (technical and operational)
- Privatization of ISS
  - Where is the value proposition ?
  - Who are the customers ?
  - Economically feasible ?
  - Business model & time horizon
  - IGA framework

HOW ARE WE PREPARING THE FUTURE ?

- Building in Space
  - Is it something new ? Some potential game changers…..
    - ☞ New materials and processes
      - NASA Friction Stir Welding
      - ESA Parabolic Flight: University of Bologna experiments
      - Additive Layer Manufacturing (3D printing)
        - Made in Space on ISS
        - D-shape Building with Lunar Regolith
    - ☞ Reusable launchers (Space X)
    - ☞ Space Debris (cost of deorbiting vs value of reusing)
- NASA “Lunar Orbital Platform – Gateway” (LOP-G) formerly known as Deep Space Gateway (DSG)
- ESA Moon Village

MANUFACTURING AND REPAIR TECHNOLOGIES IN SPACE

- Reliable and Safe (effective and clean)
- Compatible (Space environment & systems)
- Robotic (EVA assisted maintenance operations)
- Potential failures: structures, radiators, pipelines

CONSTRUCTION TECHNOLOGIES

Mechanical Fastening

Welding

- Joint strength and rigidity
- Better joint hermeticity
- Lower joint mass
- Simpler joint design
- Simpler joint manufacturing
- Higher joint reliability
- Broader repair versatility

Adhesive Bonding

Cutting and Cleaning

SPACE CUTTING REQUIREMENTS

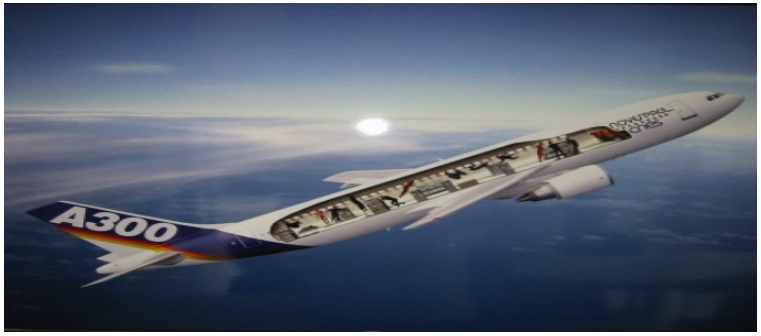
- Space standards (pressure, temperature, materials, etc)
- Machine compact, light, integrated with ISS systems
- Space environment (vacuum, temperature,…)
- Cleaning of metal surfaces for joining processes
- **Nitrojet™ in Space ?**

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

WELDING IN MICROGRAVITY

Alenia

esa

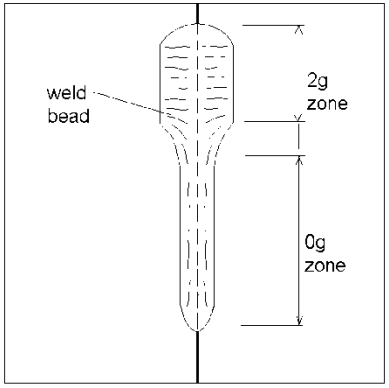


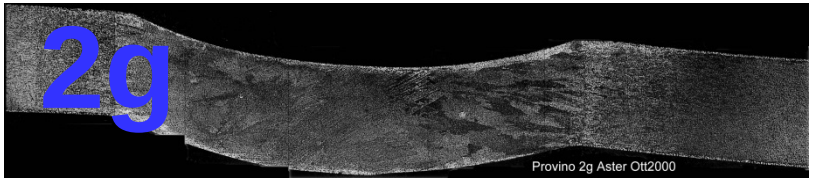
Welding payload

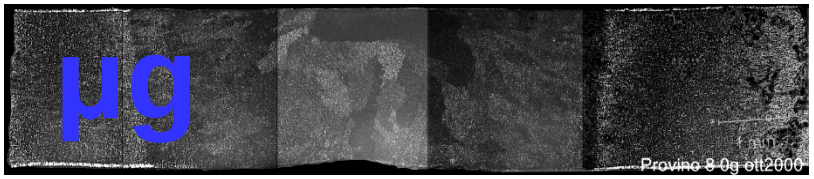
- DC GTA
- Gas system: Argon, Helium
- Welding robot 2 d.o.f.
- Pressurized Chamber

Welding process

- limited power transfer
- Marangoni effect
- Hardness increasing
- Dentritic growth
- Weld bead shape

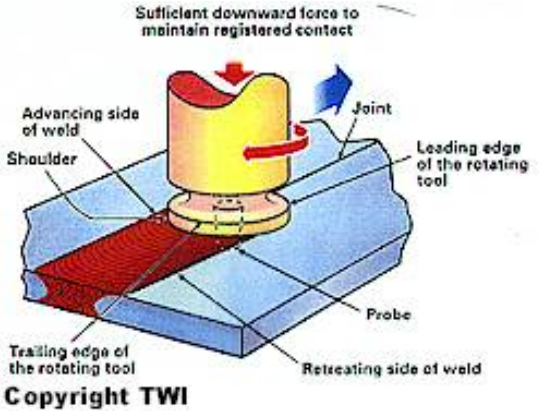






FRICTION STIR WELDING

- Friction heating produces a "plasticized" area.
- Material forged under pressure
- Metal consolidates to form a bond
- No actual melting
- Joint is stronger than parent metal



- Pin tool rotates: 180 - 300 rpm
- Applied force: 5,000 -10,000 lb/inch2
- Travel vel.: 3.5 - 5 ipm

LIVING AND WORKING IN SPACE

- Astronauts and Civil personnel
  - Suborbital Flights
    - ☞ Italy ENAC-ASI-FAA agreement
    - ☞ A Space-port in Italy?
  - Training and Fitness for flight
- Artificial Intelligence and Advanced Robotics
  - NASA Robonaut assisting astronauts during EVA
  - (new) Space Jobs ?
  - In-situ resources exploitation

ON-ORBIT ASSEMBLY AND SERVICING

- Technical Roadmap
  - Assembly (MAIT in Space)
  - Industrial players engaged worldwide already
  - Collaborative human-robotic effort (particularly in designing new concepts and solutions; identifying and selecting materials for reuse; …)
- Legal Framework
  - Space traffic management
  - Active Debris Removal
  - Ownership
  - Liability

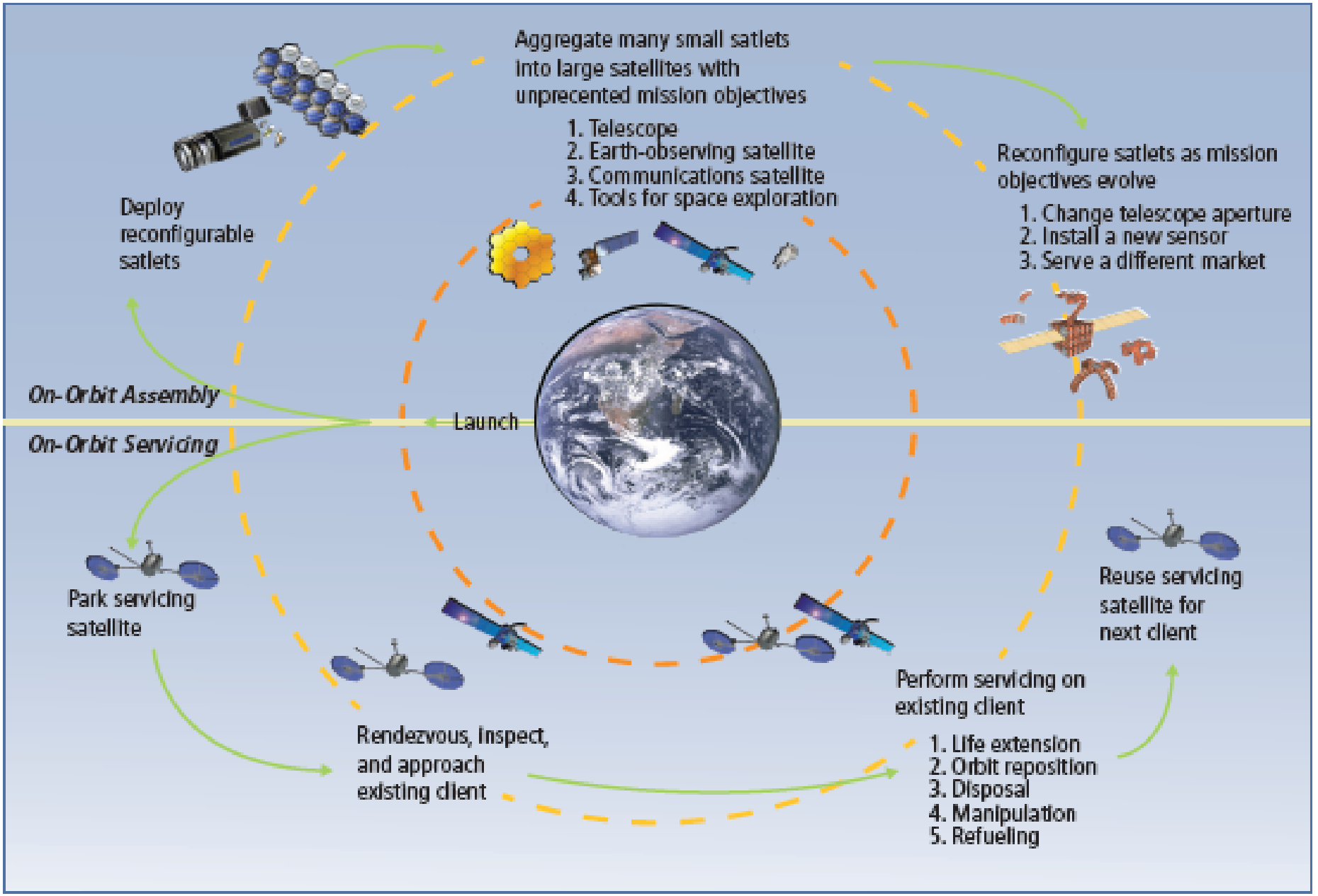


Figure 1: Distinction between on-orbit assembly and servicing paradigms (*adapted from David Barnhart, USC*).

SUBORBITAL FLIGHTS: A STEPPING STONE

Virgin Galactic recently announced that will operate its first suborbital flight, which Richard Branson will board, starting next year 1)

- **650 people who have already paid up to two hundred and fifty thousand dollars**
- **in the last decade(s) technical drawbacks have been keeping this dream from becoming a reality**


All booked: Virgin Galactic says suborbital spaceflights are full until 2021

by Jeff Foust — May 19, 2017

VSS Unity, Virgin Galactic's second SpaceShipTwo, glides during a Dec. 22 flight test. Credit: Virgin Galactic

In May 2017, the European Space Agency announced the kick-off of the construction in the UK of a rocket engine test facility, in partnership with institutional and industrial actors

- **fire airbreathing engines with the potential to revolutionise space launches, powering vehicles that can take off and land like aircraft**
- **allowing for flights up to five times the speed of sound, opening up the frontier of hypersonic air travel 2)**

1) Foust, Jeff. "All booked: Virgin Galactic says suborbital spaceflights are full until 2021." 19 May 2017. SpaceNews. Accessed 6 Jun 2017. Web: http://spacenews.com/all-booked-virgin-galactic-says-suborbital-spaceflights-are-full-until-2021/

2) ESA. "Test site for ESA-backed airbreathing engine." 4 May 2017. Accessed 6 June 2017. Web: http://www.esa.int/Our_Activities/Space_Engineering_Technology/Test_site_for_ESA-backed_airbreathing_engine

A STRATEGIC ALLIANCE BETWEEN THE AERONAUTICAL AND SPACE SECTORS ?

- Institutional side: alliance more easily supported in the United States and Japan, where the **space agencies** clearly encompass both space and aeronautics in their **mandates**.
- European industrial actors that are already engaging in R&D activities with JAXA on **hypersonic flight technology development**
- Could these new approaches boost the development and deployment of large fleets ?

A GLOBAL VISION

- Space for the benefit of humankind
  - UNISPACE+50 (June 2018)
- Exploration and space settlements
  - Societal implications and benefits
- Space Economy
  - Space Resources exploitation

innovation drivers and game changers