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## Vellore Institute of Technology honors DRDO scientist



*G Sateesh, Senior Scientist, DRDO, receiving Life Time Achievement Award from GV Selvam, Vice President, VIT University, on Saturday at Vellore*

Hyderabad: Vellore Institute of Technology (VIT), Hyderabad, presented Life Time Achievement Award to G Sateesh, senior scientist DRDO and Scientific Advisor to Defence Minister for his outstanding contribution to the field.

The Award was presented by GV Selvam, Vice President, VIT University during the one day workshop on "Advanced Manufacturing Technologies" was organised along with the Inauguration of ASM International Student Chapter at VIT, Vellore.

Presenting the award GV Selvam said that the VIT was glad to award the eminent scientist of the country serving Defence Ministry.



## The Indian Missile Journey

*By Maj Gen P K Chakravorty (Retd)*

India has traversed a long mile in the arena of missile technology. The author takes the reader on a perceptive stroll through the Indian missile development programme and also provides an overview of what its northern and western adversaries threaten it with. Today, for a country that espouses "No First Use," the Indian missile capabilities have developed adequately to serve as a substantial component of our nuclear deterrence.

## **The Indian Missile Journey**

Missiles in the Indian context were first used by Tipu Sultan during the Second Anglo-Mysore War in 1792, which resulted in 3,820 soldiers of the East India Company being taken as prisoners. We undertook our first peaceful nuclear explosion in 1974 and thereafter the search commenced for credible delivery systems. Accordingly a Special Weapons Development Team was constituted to later become the Defence Research and Development Laboratory (DRDL).

### **Integrated Guided Missile Development Programme (IGMDP)**

It was in July 1983 that IGMDP was approved by the Ministry of Defence, Government of India. The Defence Minister Shri R Venkatraman directed the Defence Research and Development Organisation (DRDO) to simultaneously develop five variants of the guided missile Trishul, Akash, Nag, Prithvi and Agni. The critical phase of development commenced when our erstwhile President, Shri A.P.J. Abdul Kalam was appointed Director DRDO. He had successfully undertaken the SLV-3 programme at ISRO and now captained India's critical missile programme. It is to the credit of DRDO that they could successfully develop three of the five missiles. Agni, Prithvi and Akash have been inducted. Trishul was foreclosed and Nag is still under trials. Further K 15 and K 4 are two missiles which are submarine launched and are undergoing successful trials.

### **Other Developments**

The development process included the areas of Cruise missile. BrahMos is a supersonic Cruise missile capable of being launched from multiple platforms on land, sea, subsurface and air against land and sea targets. It has a maximum range of 290 km, a maximum velocity of 2.5 to 2.8 Mach and cruises at an altitude of 15 km. We are trying to develop a sub sonic cruise missile Nirbhaya which has not succeeded during the four trials. DRDO is making Air Defence missiles as part of Ballistic Missile Defence. In addition, a state of the art Ballistic Missile, Prahar with a range of 150 km, has been developed.

DRDO is also developing Air Defence missiles. The Prithvi air defence missile named as Pradyumna Ballistic Missile Interceptor has a maximum interception altitude of 80 km and is capable of engaging ballistic missiles that range between 300 km to 2,000 km at a speed of Mach 5.0. Further, work is on for a missile for intercepting weapon systems which range more than 5,000 km and fly at altitudes up to 150 km. Satisfactory progress has been made in this area but the system is yet to be inducted.

### **Agni V and Agni VI**

India's dream of joining the ICBM club was fulfilled by the immaculate launch of Agni-V from the Wheelers Island, now renamed as APJ Abdul Kalam Island, at 0807 hours on 19 April 2012. The missile followed the designated trajectory and the three propulsion stages behaved correctly. The test witnessed the induction of indigenous newly developed technologies which comprised of redundant navigation systems, accurate Ring Laser Gyro based Inertial Navigation System (RINS), Micro Navigation System (MINS) and these enabled the missile to reach within a few metres of the designated target. Precise guidance was provided by the high speed onboard computer with fault tolerant software. The missile had a launch weight of 50 tons and carried a dummy warhead of 1.5 tons. There were to be six trial flights. Four flights have been successfully conducted, the last on 26 December 2016. The missile is likely to be inducted into the Strategic Forces on completion of two more tests. DRDO is planning Agni VI with an enhanced range and capability to fire 10 Multiple Independently Targeted Re-entry vehicles.

### **Ballistic Missile Defence Programme**

The Ballistic Missile Defence Programme is a two tiered system – exothermic and endothermic. The exothermic system, namely the Prithvi Air Defence (PAD) system is an endothermic missile for High Altitude exothermic interception and the Advanced Air Defence Missile (AAD) for low level endothermic interception. The PAD was first tested in November 2006 followed by AAD in December 2007. The PAD has been further developed to intercept at higher altitudes and is known as the Prithvi Defence Vehicle (PDV). Accordingly, India became the fourth country to have successfully developed an Anti Ballistic Missile System (ABS) after United States, Russia and Israel. The success of the entire system is based on the acquisition of the target missile which is done by the Sword Fish Active Electronically Scanned Array (AESA) Radar. This is a

derivative of the Israeli Green Pine Radar with the Arrow System developed to meet specific Indian needs. The radar currently has a range between 600-800 km and can spot objects as small as a cricket ball. Further enhancement to upgrade it to a range of 1500 km, is underway.

It is indeed interesting that tests for both interceptors were conducted successfully recently. On 11 February 2017 a missile fired from a ship was intercepted at an altitude of 97 km by a PDV exothermic missile. The missile has an Infra Red seeker and hit the target accurately. On 1st March 2017 an incoming missile fired from Integrated Test Range at Chandipur was successfully intercepted by AAD at an altitude of 15 km. This was an endothermic interception. With these tests The BMD system has validated its capability to intercept successfully medium range ballistic missiles travelling at speeds of Mach 3 to Mach 8. The defence against Cruise Missiles poses problems which need to be tackled by other processes.

### **Our Status in the Region**

While we are doing our utmost to develop our capabilities, it is pertinent to assess the capabilities of our western and northern adversaries. China has a lead of 17 years with regard to development of missiles. Yet, it was insecure after the successful firing of Agni-V as the strategic gap has been narrowed with all Chinese targets in range from India. Chinese have termed India as a strategic co-operator where as we certainly are a competitor. The Chinese Second Artillery which has been re-designated as PLA Rocket Forces is presently responsible for handling all types of missiles. Having been raised in 1966, their initial task was to undertake limited nuclear strikes in case of a nuclear conflict. After the First Gulf War in 1991, its role diversified to include conventional engagement against high value strategic targets.

The Second Artillery has currently a series of Cruise and Ballistic missiles. The Chinese Second Artillery is reported to have missiles deployed in three launch bases which can effectively engage targets in India. These are Kunming (Yunnan province) – two brigades DF-21(Range -2150 km); Luoyang (Henan province) – three brigades DF – 31A (Range -11200 km, MIRV) and at Delinga near Xning (Qinghai province) – three brigades of DF – 21. Each brigade has three to four battalions; each battalion has three to four launch companies and each company has one launcher. In addition there are isolated missile locations close to Lhasa in Tibet. Our entire country would be covered adequately by these land based systems, China has 62 submarines; some of these would be fitted with the JL-2, Submarine Launched Ballistic Missile with a range of 7200 km. It has satellites that could provide targeting data of our entire country. Chinese have modified missile DF21- D for engagement of large ships at sea. During the preceding year she has carried out numerous space launches, to perfect her satellite launching capability which would assist her in surveillance, reconnaissance, target acquisition, engagement of targets and post strike damage assessment. China has destroyed a satellite in outer space. In comparison our capabilities are limited.

There is an urgent need to deploy our Agni II, III and V (on successful completion of trials) and BrahMos with steep dive capability in suitable locations to cover the Chinese threat. Further, our SLBM capabilities needs to be developed, We need to have our surveillance satellites as also High Altitude Long Endurance UAVs to provide us real time targeting inputs. Our synergy in application of our resources would narrow the strategic gap, thereby dissuading them from a conflict.

Pakistan's missile build up has been all along India centric. The programme is run by Chinese and North Korean assistance. Some of the systems have been imported and the remaining are assembled in a semi knocked down or in a completely knocked down state. Pakistan possesses SRBMs (60 to 750 km), MRBMs (maximum ranges from 1500 to 2300 km), IRBMs (2500 km), Cruise Missiles: Babur-700 km and RAAD-350 km. The missile force would be primarily responsible for delivery of Pakistani nuclear weapons. Being an India centric programme, there would be matching responses to India's development. Currently, Pakistan can respond with nuclear weapons, in the event of a conventional offensive by India. Further, with its large number of nuclear weapons and missiles it boasts of a Second Strike Capability.

Our response to Pakistan need to include adequate number of Cruise missiles, for a limited conventional war and improve our Ballistic Missile Defence, which also includes the Triumpf S 400 system, to ensure effective retaliation to Pakistani nuclear weapons in a scenario where we have a declared No First Use of nuclear

weapons. Viewing the current state of affairs our Nuclear Doctrine and No First Use of nuclear weapons needs a review.

Our nation, in the current security milieu, has to be prepared for the eventuality of a two front war. There is an immediate need to induct Agni series of missiles on Chinese targets. Further, BrahMos with steep dive capability needs to be deployed. We also need to develop our own navigation and surveillance systems. DRDO needs to hasten the induction of Agni V and also improve the state of our Ballistic Missile Defence. The Ballistic Missile Defence needs to be integrated with the Russian Triumf system to optimise our Air Defence against Missiles. In consonance with this we need to develop the Multiple Independently Targeted Re-entry Vehicles as also its advanced version the Multiple Adjustable and Manoeuvrable Targeted Re-entry Vehicle. All these should be included in the Agni VI which would have a range of 8000 to 12000km. The missiles would need their own navigation system and ISRO must launch adequate number of satellites to provide our missiles their own navigation systems. With these force multipliers India would have a credible missile system which would enable us to deter both China and Pakistan against undertaking any adventure. , our BMD gives us sufficient capability against Ballistic Missiles. Efforts must be made to improve our defence against Cruise Missiles.

### **Conclusion**

Current usage of missiles in the Gulf Wars, Afghanistan, Gaza and Libya demonstrate the capability of the weapon systems to destroy targets in the tactical, operational and strategic areas with devastating effects. Our development of the BMD has also enhanced our defence capability against these missiles. Our current state of development needs to be enhanced to strategically engage China; a country that has recently turned more assertive with its territorial claims. Further, we need to exploit these systems in mountainous areas where possibly our future wars are anticipated. The success of the steep dive test by BrahMos calls for speedy deployment of the missile in mountains. At the macro level, the entire process is currently an ongoing pursuit, and needs to be monitored at the national level.



*Thu, 09 Mar, 2017*

## **Agusta Accused of Supplying Damaged Copter**

*By Manu Pubby*

An Agusta AW 139 helicopter ordered by an Indian charter company has propelled the Italian manufacturer into another row in the country about five years after it was embroiled in a multi-crore bribery scandal involving supply of choppers meant to ferry VVIPs.

Spectrum Aero Pvt Ltd, which had ordered the helicopter for high-end lease, has said that the chopper was delivered in a damaged condition, people familiar with the matter told ET on condition of anonymity.

The Delhi-based company has said that the chopper's tail boom was broken, it had incorrect identification plates and it lacked an airworthiness certificate when it arrived from Italy in January. It has asked the helicopter maker, Leonardo S.p.A., to either supply it with a new helicopter or refund the money.

A detailed questionnaire sent by ET to Leonardo did not elicit any response till late evening on Wednesday.

The company was earlier an AngloItalian arm called AgustaWestland, which had in 2010 signed a €60 million (about `3,546 crore at the time) contract to supply 12 AW-101 helicopters to the Indian Air Force. Eight of these helicopters were to be used to ferry VVIPs such as the Prime Minister and President. However, the VVIP choppers have been mothballed at the Palam airbase since the deal got mired in the bribery scam. A Spectrum Aero spokesperson alleged that the chopper was damaged twice in transit, including an accident where it fell off a truck during the loading process onto a transport ship. "During transit the chopper got damaged twice, which is highly unusual. We have been in dialogue with the Agusta team for some time but have not reached a satisfactory conclusion as yet," the spokesperson told ET.

The charter company, which was originally scheduled to receive the AW 139 in June 2016, has claimed business losses as well due to the delayed delivery. The helicopter had to undergo three months of repairs after the first accident, when it fell off a truck in June last year, the people cited earlier said. AgustaWestland had courted another controversy in India since the 2012 VVIP chopper scam that led to cancellation of the contract with the defence ministry. The Rajasthan government cancelled a tender it had issued to obtain an Agusta chopper after ET reported on December 14, 2016 that the tendering process violated competitive norms. The VVIP chopper scam case is currently being probed by the CBI.

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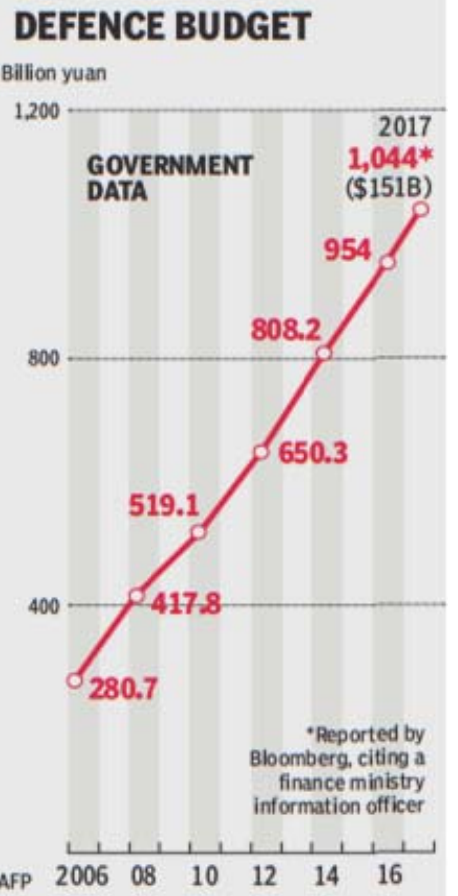
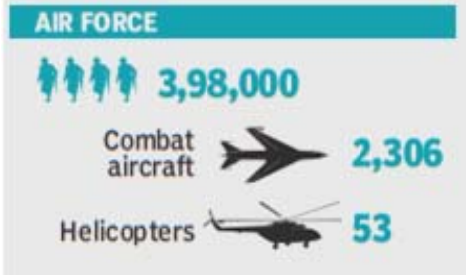
# THE TIMES OF INDIA

Thu, 09 Mar, 2017

## ARMS & THE DRAGON: CHINA'S DEFENCE SPEND & FIREPOWER

Right after US President Donald Trump called for a 10% increase in his country's defence budget, China announced a 7% hike in its military spending for the year. Although the increase by China is its smallest in years, the country's defence spend is second only to that of the US. Here's a look at where the Chinese military, the largest in terms of personnel, stands...

### MAIN EQUIPMENT DEPLOYED AND SPENDING



Based on an analysis by the International Institute for Strategic Studies

Source: AFP

Thu, 09 Mar, 2017

## China to deploy most advanced rescue ship in SCS

Beijing: China today said it will deploy a new rescue ship capable of conducting air, sea and underwater searches simultaneously in the disputed South China Sea. The ship, Nanhaijiu 102, is the most advanced rescue vessel in the area and will play a role in emergencies, the Chinese Ministry of Transport said.

The all-weather, high-powered rescue ship designed and built by China, is 127 metres long and 16 metres wide, with displacement of 7,300 tonnes and range of 16,000 nautical miles, state-run Xinhua news agency reported. The choice of placement of the vessel in the South China Sea is significant as China is firming up its hold on the area with artificial islands.

China claims almost all of the South China Sea. The Philippines, Malaysia, Vietnam, Brunei and Taiwan have made counter claims. Carrying a towing system and autonomous underwater vehicle that can dive as deep as 6,000 metres, the ship is the country's first rescue ship that can conduct air, sea and underwater searches at the same time. The ministry said the ship, which can rescue 200 people at a time, is designed for bad sea conditions and is suitable for the refueling and landing of helicopters.

China has 74 special rescue ships, among which 31 are in southern sea areas.



Thu, 09 Mar, 2017

## China proposes 'double suspension' formula to end Korean crisis

*Beijing asks Pyongyang to suspend missile tests, tells U.S. to stop military drills*

China on Wednesday proposed a "double suspension" formula to defuse the crisis on the Korean Peninsula as part of its new assertive approach to shoulder greater global responsibilities within the framework of the UN.

"As a first step, the Democratic People's Republic of Korea (DPRK) may suspend its nuclear and missile activities in exchange for the suspension of large-scale U.S. Republic of Korea (ROK) military exercises," Chinese Foreign Minister Wang Yi said at a media conference on the sidelines of the annual session of the National People's Congress.

This will help the parties to break out of the security dilemma and return to the negotiating table, he observed. "We may follow the dual-track approach of denuclearising the peninsula on the one hand and establishing a peace mechanism on the other."

The Chinese Foreign Minister compared the missile tests of the North and the joint drills across the border in South Korea to two "accelerating trains coming toward each other". "Holding nuclear weapons won't bring security, using military force won't be a way out," Mr. Wang said, in a message to Pyongyang and Seoul. "There remains a chance of resuming talks, there is still hope for peace."

Mr. Wang stressed that the DPRK and the U.S. were the main parties to the nuclear issue on the Korean Peninsula, but as a next-door neighbour with a lips-and-teeth relationship with the Peninsula, China's role in the resolution of the issue was indispensable.

In response to a question, Mr. Wang highlighted that the Brazil- Russia-India-China-South Africa (BRICS) grouping was set for deepening its engagement with the Global South under a BRICSplus approach.

Dialogue partnership

He stressed that under the stewardship of China, which will host the BRICS summit this year, the emerging country bloc will explore establishing a dialogue partnership with other major developing countries.

“We will widen the circle of friends of the BRICS and turn it into the most influential platform for south-south cooperation in the world.”

At a time when the U.S. appeared to be looking inwards, the Chinese Minister affirmed that his country would champion inclusive globalisation, within the framework of the UN. He said President Xi Jinping’s January visit to international organisations had sent out a clear message that China strongly supported multilateralism, along with its abiding commitment to the UNcentred multilateral system.

“In China’s view, the current international system was built by our forefathers from the ashes of the Second World War. It is a result of our common effort and wisdom. It is like a well-designed building with multilateralism as its cornerstone and the UN and other international organisations as important pillars.”

In his free-wheeling annual press conference that lasted nearly two hours, Mr. Wang signalled Beijing’s support for a trilateral relationship among China, Russia and the United States. “We believe the three countries can develop healthy and positive relations so that jointly we can fulfil our responsibilities for world peace and development.”



Thu, 09 Mar, 2017

## China calls on US, N Korea to avert ‘collision’

**BEIJING:** China warned on Wednesday that North Korea and the US were like two trains racing towards a “head-on collision,” calling on both sides to apply the brakes and avert a security crisis.

Foreign Minister Wang Yi’s warning came after a cascade of events that has sent tensions soaring, including provocative North Korean missile tests and annual US-South Korean war-games that infuriate Pyongyang.

Beijing itself is particularly concerned over a US missile-defence system being rolled out in South Korea as a shield against the North Korean threat, which Wang said also “undermines China’s strategic security.” He called on North Korea to suspend nuclear and missile activities in exchange for the US and South Korea halting the exercises.

“The two sides are like two accelerating trains coming

toward each other with neither side willing to give way,” Wang said at a press conference on the sidelines of China’s annual parliament session.

“The question is: are the two sides really ready for a head-on collision? Our priority now is to flash the red light and apply the brakes on both trains.”



Thu, 09 Mar, 2017

## Mars trip could up leukaemia risk in astronauts

Scientists, studying how a three-year flight to Mars may affect astronauts, said that radiation encountered in deep space travel might increase the risk of leukaemia.

Nasa researchers used mice transplanted with human stem cells for their research. “Our results show radiation exposure could potentially increase the risk of leukaemia in two ways,” said Christopher Porada, associate professor at Wake Forest Institute for Regenerative Medicine in the US.

Researchers are presently testing a common dietary supplement to protect astronauts from these damaging effects. Radiation exposure is believed to be one of the most dangerous aspects of travelling to the Red Planet.. The goal of the study was to assess the direct effects of simulated solar energetic particles (SEP) and galactic cosmic ray (GCR) radiation on human hematopoietic stem cells (HSCs). These stem cells comprise less than 0.1% of the bone marrow of adults, but produce the many types of blood cells that circulate through the body and work to transport oxygen, fight infection, and eliminate malignant human HSCs from healthy donors of



typical astronaut age (30-55 years) were exposed to relevant doses of protons and iron ions at the Nasa Space Radiation Laboratory.

These exposure levels that simulated deep space radiation were found to dramatically affect the health and function of the HSCs. "Radiation exposure at the was highly deleterious to HSC function, reducing their ability to produce almost all types of blood cells, often by 60-80%," said Porada.

"This could translate into a severely weakened immune system and anaemia during prolonged missions in deep space," he said. This study was the first to show a damaging effect of low, mission-relevant doses of space radiation, he said.



Thu, 09 Mar, 2017

## ISRO nano twins stabilise in space

*The INS 1A and INS 1B, experimental nano satellites built by ISRO, were among the 104 satellites launched by ISRO's PSLV C37 rocket.*

The two nano satellites of ISRO that had caused problems since being launched on February 15 on a PSLV workhorse rocket have stabilised, the space agency informed on Wednesday. The INS 1A and INS 1B, experimental nano satellites built by ISRO, were among the 104 satellites launched by ISRO's PSLV C37 rocket. All the other satellites — among them ISRO's Cartosat 2D and 88 nano satellites belonging to the US start-up Planet Labs — were reported to be stable, ISRO had reported trouble with stabilising the nano satellites.

"After initial hiccups, things have settled and the satellites are under our control," the director of ISRO's satellite centre, Mylaswamy Annadurai, said. "Unlike large satellites, where we are able to provide more control system like thrusters, in a nano satellite the control facility is limited as availability of power is limited. Nano satellites are an experimental programme in ISRO," Annadurai said.

The nano satellites, weighing 8.4 kg and 9.7 kg, were reported to be displaying uneven parameters after launch. Sources in the space agency reported "some difficulties in signals" between the two satellites and ground stations. ISRO put out images taken from the Cartosat 2D satellite on its website a couple days after the launch but did not reveal the status of INS 1A and INS 1B.

The nano satellites are carrying instruments from ISRO's Space Application Centre and the Laboratory for Electro Optic Systems. Data gathered will be used by the two agencies. "The nano satellites are an experimental class of satellites introduced by ISRO because there are requests from academic institutions to use them for data collection. The universities do not have the knowledge to build satellites and tend to take a long time... We want them to focus on the instruments as we can provide the nano satellite bus," an ISRO official said.

In a record-breaking launch on February 15, PSLV C 37 had carried 88 nano satellites from Planet Labs, eight satellites from another US mapping start-up called Spire, one each from the Netherlands, Israel, the UAE, Kazakhstan and Switzerland, apart from ISRO'S two nano satellites and the Cartosat 2 series satellite.

## THE ASIAN AGE

Thu, 09 Mar, 2017

## ICSSR seeks more funds for social sciences

*The ICSSR was established in 1969 to promote research in social sciences in the country.*

New Delhi: The Indian Council of Social Science Research (ICSSR) has sought additional funding from the Union human resource development ministry for research in the field of social sciences.

Speaking to this newspaper on the sidelines of a two-day seminar, ICSSR member-secretary Virendra Kumar Malhotra emphasised on the need for increased funding for the sector.

“There is definitely a need for an increase in funding for research in the social science sector. I have taken up the matter with Union HRD minister Prakash Javadekar who has been positive on the issue,” Prof. Malhotra said.

He said that there was a need to increase inter-disciplinary research among various nations and disciplines. “As part of an increased inter-disciplinary research outreach, we are collaborating with 25 nations across the globe,” Prof Malhotra said.

As part of the enhanced engagement with foreign nations, several workshops and seminars have also taken place, he added.

It is understood that social sciences only get about two per cent of the funds when compared to science subjects, and there has been an attempt at garnering more funds for the discipline. The ICSSR was established in 1969 to promote research in social sciences in the country.

The ICSSR advises the government on all matters pertaining to social science research as may be referred to it from time to time and takes such measures generally as may be necessary from time to time to promote social science research and its utilisation.



Thu, 09 Mar, 2017

## For IISc, big joy in ‘small’ list

*Times Higher Education ranks IISc among the world’s top 10 small universities, institute director credits a century of hard work and the independence given to researchers*

The Indian Institute of Science, which was among the world’s top 100 engineering and technology universities in 2015 in annual rankings put out by the UK-based Times Higher Education (THE), has now taken a place among the top 20 ‘small’ universities for the year 2016-17. In rankings released by THE on Tuesday, IISc, Bengaluru was placed No. 8 in the list of the World’s Best Small Universities. THE introduced this new category in 2015-16. IIT Guwahati and Savitribai Phule Pune University were placed 14th and 18th respectively in the list last year.

To qualify for the Best Small Universities list, institutions had to feature in THE’s overall World University Rankings for 2016-17, had to be teaching more than 4 subjects, and have less than 5,000 students, according to a statement on the new rankings put out by THE.

IISc has consistently been the top ranked Indian university in THE rankings over the last few years — it is now in the 201-250 band globally. According to THE, “India’s leading university — the Indian Institute of Science — is edging closer to the top 200, claiming a spot in the 201-250 band, its highest ever position”.

IISc Director Prof Anurag Kumar said, “I have not seen the numbers but this (World’s Best Small Universities) seems to be a new category at THE. One of our strengths is research, and we would expect to score best in that category. This ranking is the result of over 100 years of hard work, a high quality faculty, independence given to researchers, government support and an ability to compete with the top universities.”

Oddly, despite being the top Indian university, with a ranking in the 251-300 band in 2015-16, IISc did not feature in the top 20 small universities category that year. IIT Guwahati, which ranked in the 501-600 band, and Savitribai Phule Pune University, which ranked in the 601-800 band, were the Indian universities that made it instead.

The California Institute of Technology, or Caltech, has retained its position from 2016 as the world’s top small university in the 2017 rankings. Caltech is incidentally also the only university in the small universities

category to also feature among THE's rankings of top 10 universities in the world. It has come in at No. 2 behind table leader University of Oxford.

The École Normale Supérieure, based in Paris, is placed No. 2 in the small universities' list, and is at No. 66 in the World University Rankings. Pohang University of Science and Technology, South Korea, the top small Asian university, is at No. 3 in the small universities list, and at No. 104 in the world rankings.

BEST SMALL UNIVERSITIES		
Rank	University	WURrank 2016-17
1	California Institute of Technology, USA	2
2	École Normale Supérieure, France	66
3	Pohang University of Science and Technology, South Korea	104*
4	École Polytechnique, France	116*
5	Scuola Normale Superiore di Pisa, Italy	137*
6	Scuola Superiore Sant'Anna, Italy	190*
7	École Normale Supérieure de Lyon, France	201-250
8	Indian Institute of Science, India	201-250
9	Swedish University of Agricultural Sciences, Sweden	251-300
10	Free University of Bozen-Bolzano, Italy	251-300

WUR: World University Rankings \*One or more other universities have the same rank

<p><b>ELIGIBILITY</b> To qualify for the Best Small Universities list, an institution must appear in Times Higher Education's World University Rankings 2016-17, teach more than 4 subjects, have fewer than 5,000 students.</p> <p><b>NUMBERS</b> Average number of students at an institution in the 2017 World's Best Small Universities ranking is 3,038. By</p>	<p>contrast, the average number of students at an institution in THE's main global ranking is 24,953.</p> <p><b>VOICES</b> Many students prefer the smaller class sizes, closer relationships with teachers, greater sense of community. Small universities in larger cities offer perks of an intimate campus amid metropolitan life, students say.</p>
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WORLD UNIVERSITY RANKINGS 2016-17		
1	University of Oxford	Oxford, United Kingdom
2	California Institute of Technology	Pasadena, California, US
3	Stanford University	Stanford, California, US
4	University of Cambridge	Cambridge, United Kingdom
5	Massachusetts Institute of Technology	Cambridge, Massachusetts, US
6	Harvard University	Cambridge, Massachusetts, US
7	Princeton University	Princeton, New Jersey, US
8	Imperial College London	London, United Kingdom
9	ETH Zürich	Zürich, Switzerland
10	University of California, Berkeley	Berkeley, California, US
10	University of Chicago	Chicago, Illinois, US

The world university rankings are based on marks allotted under five key areas — teaching, research, citations, industry income and international outlook — with a maximum of 100 marks in each category and for overall

performance. According to countrywise data put out by THE, universities in Singapore are among the best in the world on all five counts, while Indian universities tend to be weak on scores for citations and international outlook.

Caltech — No. 2 in the world rankings and No. 1 in the small universities rankings — had an overall score of 94.3, with 99.8 for citations, 90.8 for industry income, 63.4 for international outlook, 95.7 for research, and 95.9 for teaching. Caltech has 2,181 students and a teacher-student ratio of 6.7. It has 27% foreign students.

IISc — No. 8 — scored 47.3 for citations, 48 for industry income, 18.1 for international outlook, 49.2 for research, and 50.1 for teaching. IISc has a total of 3,398 students, making it eligible for the small universities category, and a 8.3 student-teacher ratio. However, only 1% of its students are foreigners.

The South Korean Pohang University of Science and Technology has a overall rating of 59.6, with citations registering 79.2, industry income 99.6, international outlook 34.2, research 48.7 and teaching 53.8. The university has 3,017 students with a teacher-student ratio of 10.

Despite its strong showing in the THE small university rankings, IISc has lagged in recent years in other rankings for international universities. In the Shanghai rankings or Academic Ranking of World Universities put out by the Shanghai Jiao Tong University, IISc's best ranking was between 201-300 — back in 2003. Since 2005, IISc has been slotted consistently in the 301-400 rank bracket.

In the engineering category in the Shanghai rankings, IISc reached its top ranking in 2007, when it was slotted between the 77 and 106 ranks. The two subjects in which IISc has had good rankings over the years in the Shanghai list are chemistry, where it reached a high rank of 43 in 2013, and computer science, where it ranked at a high of 51-75 in 2013.

### **These are the world's best universities**

The 2016-17 Times Higher Education World University Rankings published Tuesday is its biggest international list yet — more than the 801 universities listed last year. THE judges universities across their core missions of teaching, research, knowledge transfer and international outlook, using 13 performance indicators. The 2016-17 list includes institutions from 79 countries, representing an elite 5% of the world's higher education institutions. For the first time since the THE's inception in 2004, an American institution has failed to take the top spot — however, as many as 148 of the total 980 universities in the list, 63 of the top 200, and 3 of the top 5 are still American.

### **How Brics Fare**

Brazil: 1 university in top 400, down from 2 last year

Russia: 1 university in top 300, down from 4 last year

India: 2 universities in top 400, 5 in the top 500

China: 2 in top 100 (5 including Hong Kong)

South Africa: 2 in top 200

10 Debutant Countries

Algeria, Bulgaria, Costa Rica, Croatia, Georgia, Kuwait, the Philippines, Sri Lanka, Tunisia, Venezuela.

### **Outside North America & Europe in Top 100**

**24.** National University of Singapore, Singapore

**29.** Peking University, Beijing, China

**33.** University of Melbourne, Melbourne, Australia

**35.** Tsinghua University, Beijing, China

**39.** University of Tokyo, Tokyo, Japan

**43.** University of Hong Kong, Hong Kong

**47.** Australian National University, Canberra, Australia

**49.** Hong Kong University of Science and Technology, Hong Kong

**54.** Nanyang Technological University, Singapore

**60.** University of Queensland, Brisbane, Australia

**60.** University of Sydney, Sydney, Australia

**72.** Seoul National University, Seoul, South Korea

**74.** Monash University, Melbourne, Australia

**76.** Chinese University of Hong Kong, Hong Kong

**78.** University of New South Wales, Sydney, Australia

**89.** Korea Advanced Institute of Science and Technology Daejeon, South Korea

**91.** Kyoto University, Kyoto, Japan