PolyU technology supports moon landing and exploration

理大科研支援登月及探月工程

A camera pointing system jointly developed by PolyU and the China Academy of Space Technology (CAST) has successfully landed on the moon. The innovative lunar mapping techniques developed by the University have also contributed to the moon landing mission.

由理大與中國空間技術研究院合力研發的「相機指向機構系統」已成功登月。理大開發的高精密度月球地形測繪新技術亦為是次登月作出貢獻。

Scientists at mission control held their collective breath on 14 December 2013 when the Chang'e-3 lander touched down smoothly on the moon. China's first moon landing, in the Sinus Iridum or 'Bay of Rainbows' at 44.1° latitude north of the moon, marked the pinnacle of national technological achievement and brought with it a local touch.

Onboard the probe was the camera pointing system developed jointly by researchers at PolyU and CAST, the latest outcome of ongoing collaboration between the two organizations. Established in 1968 with the late aerospace scientist Qian Xuesen as its founding president, CAST is the most important research and engineering base for China's space flight missions. Back in 2010, CAST signed an agreement with PolyU to establish the Joint Laboratory in Precision Engineering for Space Applications, to which it also donated advanced space research equipment. In April 2012, both parties signed a pact to develop a space tool for collecting lunar rock samples in the third phase of China's lunar exploration programme. In March 2013, PolyU further signed an agreement with CAST to establish the Joint Laboratory in Mechanics and Space Environment Engineering - the second joint laboratory co-founded by both parties.

零一三年十二月十四日嫦娥三號落月之時，控制中心全場科學家屏氣凝神地目睹整個過程，見證嫦娥三號在月球北緯44.1度的虹灣區登陸的歷史性一刻。這不單標誌著國家航天科技跨進了一大步，更意味著香港成功為這探月工程獻出一分力。

是次隨月球探測器登月的「相機指向機構系統」由理大及中國空間技術研究院專家共同研發，更是近期雙方合作的重要成果。中國空間技術研究院成立於一九六八年，已故錢學森教授是其首任院長，現為目前國內最具實力的空間技術及其產品的主要研製基地，協助中國航太事業發展。雙方早於二零一零年簽約合作建立「空間精密機械技術聯合實驗室」，由院方贈送用於研發空間設備的實驗基礎設施。二零一二年四月，雙方再協定合作進行國家探月工程第三階段的科研工作，共同研發登月取樣儀器。翌年三月，兩所機構進一步簽訂協議，共建第二所聯合實驗室，名為「力學與空間環境工程技術聯合實驗室」。

Historical mission in a place way out of reach

Being the first Hong Kong made instrument deployed in the Chinese lunar exploration programme, the Camera Pointing System is installed in the upper part of the lander. The sophisticated space tool capable of moving through 120 degrees vertically and 350 degrees sideway controls the camera that has been capturing images of the moon's surface and the lander's automated rover named Yutu, or Jade Rabbit. At only 85 cm long, 27 cm wide, 16 cm deep and weighing 2.8 kg, the system is an engineering marvel.

Lead developer on the camera-pointing project was Prof. Yung Kai-leung, Associate Head of PolyU's Department of Industrial and Systems Engineering. Prof. Yung has created ingenious designs in the space engineering field. The Mars Rock Corer developed by Prof. Yung and his expert partners for the European Space Agency's Mars Express Mission in 2003 could grind, drill, core and grip rock samples as though using chopsticks. The team also designed the Space Holinser Forceps for the then MIR Space Station and the soil preparation system for the Sino-Russian Space Mission in 2011. All of these tools were constructed in PolyU's Industrial Centre, where another member of the camera-pointing project team, Ir Dr Robert W.M. Tam, is Associate Director.

Prof. Yung explained that his team had manifold concerns in the design process for the camera pointing system, and needed to spread stress "evenly across the whole device by the optimal use of material properties". They also needed to select materials very carefully. "We used a number of avionic materials", he said, "because we had to consider the combination of materials in terms of the coefficient of thermal expansion as well as strength".

Other vital considerations for use in the avionic environment were that "many materials do not behave the same way as on Earth with respect to the friction between them as well as chemical compatibility with different types of lubrication". Prof. Yung recalled that lubricants, in particular, needed intensive research. The result was a series of lubricants selected for particular parts of the system: "in some places we had to use solid lubricants, and we had to use liquid as well as lubrication paste for certain mechanisms".

Prof. Yung knows only too well that there is so little margin for error in space engineering. Yet when images started reaching mission control in Beijing the next day, the system had been proven durable enough to work 384,400 kilometres away in extreme temperatures at one-sixth of Earth's gravity. At the time he remarked that "I am getting more confident that the device will be fine."

Prof. Yung explained that the images showed many big rocks in the landing area, which the Yutu rover fortunately missed. Even so, the site was relatively smooth in lunar terms, thanks in large part to the preparatory research of another PolyU academic, Dr Wu Bo.

1

2

在遙不可及之地完成歷史任務

「相機指向機構系統」是首部用於中國探月工程項目，並在香港製造的儀器。這個精密系統安裝於嫦娥三號的著陸器頂部，能俯仰轉動120度，偏航轉動350度，以拍攝月貌全景成影像，以及取名「玉兔」的整個巡視器（月球車）。這系統只高85厘米、寬27厘米、深16厘米、重2.8公斤，堪稱一項工程奇蹟。

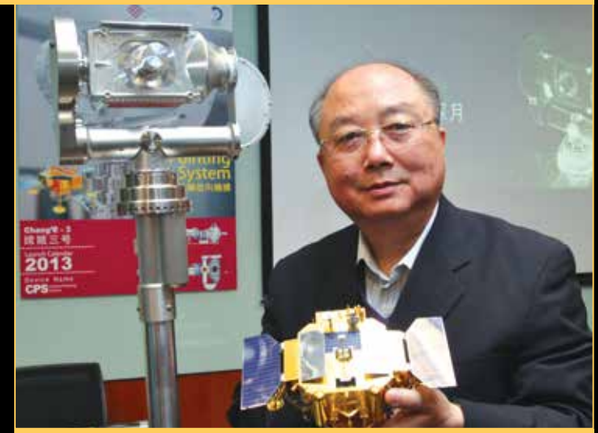
理大工業及系統工程學系副系主任容啟亮教授就是該系統的主要研發者。容教授在航天工程界創造了多項精巧獨特的設計。他與合作夥伴曾為歐洲太空總署二零零三年火星快車任務研發融合了中國筷子特性、可磨、鑽、挖及抓取土質樣本的「岩芯取樣器」；並為前和平號太空站研發太空鉗，也曾為二零一一年的中俄聯合探索火星任務研發「行星表土準備系統」。這些太空儀器均是在配備精良的理大工業中心製造，而另一開發「相機指向機構系統」的團隊成員正是工業中心副總監譚惠民博士、工程師。

容教授的團隊在設計「相機指向機構系統」時有多個層面的考慮。他指出「重點是盡量利用物料特性，將不同的應力分散」。因此，他們需要嚴謹挑選物料。他續說：「我們用上很多不同的航天物料；考慮物料的匹配，包括物料不同的膨脹系數及物料的堅硬度。」

他表示在航天環境下，「很多物料在相互間的磨擦跟地面上有所不同，它們對潤滑劑的反應也完全不同」。容教授的團隊於是深入研究不同的潤滑劑，務求在不同設計中選用最合適的潤滑劑，他指出「有些機械需用上固體潤滑劑，有些則用液體或漿狀，以配合不同需要」。

容教授瞭解到航天工程技術只容許極少的偏差。在月球影像圖傳達北京控制中心之後，證明了這系統足以在月球表面巨大溫差下，在重力只有地球六分一的環境中使用，並在384,400公里外遠程持久運作。「我越來越對這儀器充滿信心！」容教授當時說道。

容教授進一步解釋，影像圖顯示在著陸處附近有很多大石塊，幸好月球車「玉兔號」能避開它們。其實，著陸區選點已是月球上相對較平坦的位置，這在很大程度上有賴另一理大學者吳波博士的詳細分析。



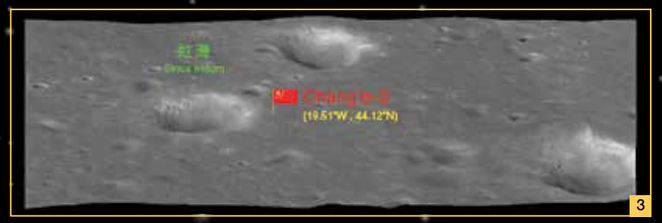
> We used a number of avionic materials because we had to consider the combination of materials in terms of the coefficient of thermal expansion as well as strength.
>
> 我們用上很多不同的航天物料；考慮物料的匹配，包括物料不同的膨脹系數及物料的堅硬度。

1. *(From left) Prof. Yung Kai-leung, Associate Head, Department of Industrial and Systems Engineering; Ir Dr Robert W.M. Tam, Associate Director, Industrial Centre; Dr Wu Bo, Assistant Professor, Department of Land Surveying and Geo-Informatics; and Prof. Ding Xiao-li, Chair Professor and Head, Department of Land Surveying and Geo-Informatics.*
   （左起）工業及系統工程學系副系主任容啟亮教授、工業中心副總監譚惠民博士、工程師、土地測量及地理資訊學系助理教授吳波博士，以及土地測量及地理資訊學系講座教授兼系主任丁曉利教授。
2. *Ir Dr Robert W.M. Tam explaining the operation of the camera pointing system.*
   譚惠民博士、工程師解釋「相機指向機構系統」的運作。

Smoothing the way for soft-landing

An Assistant Professor at the Department of Land Surveying and Geo-Informatics, Dr Wu devised innovative lunar mapping techniques that were instrumental in laying the groundwork for site selection on the lunar surface. At the invitation of CAST, Dr Wu and his team began working on a project entitled "Chang'e-3 Lunar Probe – Lunar Topographic Modelling and Analysis in Sinus Iridum Area" in August 2012.

The Sinus Iridum was chosen as the general landing area for its flat surface, lack of large impact craters and average slope of only 2.2 degrees. To narrow down the possible landing sites within the area, the team used remote sensing data collected from a range of sensors, including those aboard the Chang'e-2 lunar orbiter, to create extremely precise, high-resolution topographic models. They also conducted detailed analyses of the terrain slope and crater distribution information of the area and several key candidate landing regions.



3

3. 3D view of the landing site of Chang'e-3 in the Sinus Iridum or 'Bay of Rainbows'.
嫦娥三號在虹灣區登陸位置的三維視圖。

4. Participating in the Chang'e-3 mission are members from PolyU's Department of Industrial and Systems Engineering, Industrial Centre and Department of Land Surveying and Geo-Informatics.
參與嫦娥三號登月任務的理大團隊成員，來自工業及系統工程學系、工業中心，以及土地測量及地理資訊學系。

5. Dr Wu Bo introducing the high-precision lunar mapping techniques.
吳波博士介紹高精密度月球地形測繪技術。

Dr Wu earlier received funding from the Hong Kong Research Grants Council for his research on multi-source lunar remote sensing data integration for high-precision topographic modelling. He developed lunar mapping techniques by synergistically integrating lunar remote sensing imagery and laser altimeter data, which laid a solid foundation for the work of topographic modelling and analysis of the Chang'e-3 landing site.

The two local contributions to the lunar mission's success provide ample evidence of PolyU's commitment to developing practical knowledge and applications for the benefit of humankind. In a narrower sense, they could also inspire the younger generation to take up scientific careers. Prof. Yung expressed hope that local participation in the space mission could arouse greater interest in science among local youngsters.

There will certainly be scope for involvement in space exploration, and Prof. Yung himself is preparing for further work for the lunar mission. He has been appointed by the China National Space Administration's Lunar Exploration Program Center as an Expert Member for the third phase of the lunar exploration program. He will again collaborate with mainland experts to develop a surface sampling and packing system, drawing on his wealth of experience in the area. It will be China's first space mission to collect surface sampling from the moon. He is also looking forward to exploring other avenues of participation in Chinese space exploration, with the view to developing new concepts that can eventually be put to civilian use. Whether in space or on Earth, science is always on the move.

為軟著陸分析預備

理大土地測量及地理資訊學系助理教授吳波博士設計的嶄新高精密度月球地形測繪技術，為是次登月行動選擇合適的著陸地點。應中國空間技術研究院邀請，吳博士與其團隊自二零一二年八月開始，著手月球表面虹灣區的地形地貌分析研究項目。

虹灣區被選為著陸點是由於該處較為平坦，沒有較大的撞擊坑，而平均坡度只有2.2度。為收窄適合著陸處的範圍，團隊採用了經不同傳感器收集的遙感數據，包括從嫦娥二號月球探測器取得的影像，進行高精密度及高分辨率的地形測繪，並對虹灣區及幾個主要考慮作為著陸點的地方作坡度及撞擊坑分佈的詳細分析。

吳博士早前獲得香港研究資助局的資助，進行基於多源月球遙感數據集成的高精密度地形建模研究，研發了集成月球遙感影像與激光高度計數據的月球測繪新技術等，為嫦娥三號著陸區的地形地貌分析工作打下了堅實的基礎。

上述兩項本地科研成就對國家探月工程的貢獻，正好引證理大致力探究和應用知識，以期造福人類，並吸引年青一代投身科學事業。容教授更期望香港參與航天工程計劃，能喚起本地年青人對科學的興趣。

太空探索工程涉及不同領域，亦存在很大的發展空間。容教授率先垂範，著手準備探月工程的下一步工作。他早前獲國家航天局探月與航太工程中心委任為國家探月工程第三期專家組成員，並將再度與內地專家合作，研發一具「表取採樣執行裝置原理樣機」。這將會是中國航太史上首次採集月壤的任務。此外，他期望以不同途徑獻力祖國的航天發展工作，並開發能擴展至民用的新概念。不論是在太空或地球，科學發展總是一日千里，不斷向前。


4

5