Full picture

Iran's first launch of a 'military' satellite has been closely scrutinised by the OSINT community. **Tony Roper** surveys how a range of open sources has enabled assessments about the satellite's functionality and utility.

Key points

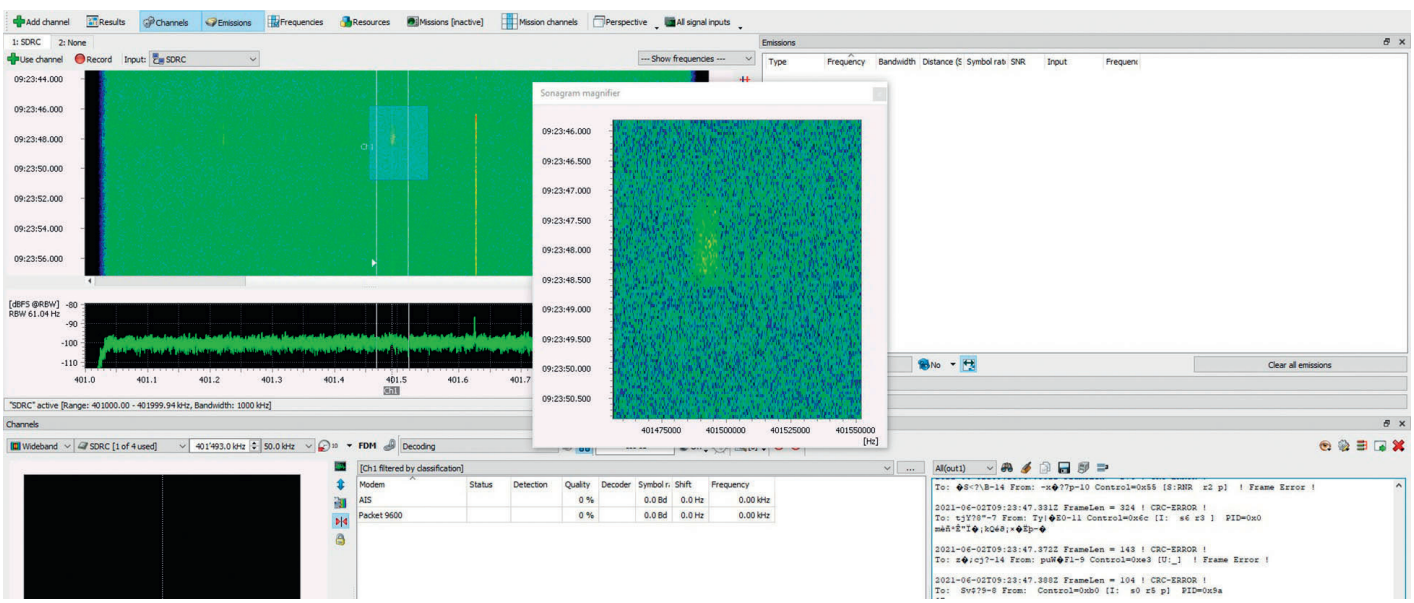
- Using online sources and freely available tracking software, OSINT analysts worldwide have been able to monitor Iran's first claimed 'military' satellite, the Nour 01, which was launched in April 2020.
- The downlink data received from Nour is in a standard unencrypted packet form, generally not expected for a military satellite transmitting classified data, and this enables its processing using open-source software.
- Although Nour is sending data, this could be solely for test monitoring by a basic ground station at the Shahrud Space Centre, and early Iranian claims that Nour could transmit imagery and other intelligence may therefore not be true.

A little more than one year after the Iranian Islamic Revolution Guards Corps (IRGC) launched a Qased rocket from the Shahrud Space Centre in the Semnan province of Iran (36.200818, 55.333743), very little is known about the Nour 01 satellite (also referred to as Noor 01, alternative spelling Nur, meaning 'light') that the Qased deployed into the Earth's orbit on 22 April 2020 at 0359 co-ordinated universal time (UTC). The Nour entered a 409.7 km perigee/423.1 km apogee that takes approximately 93 minutes to complete one revolution around the Earth.

On 23 April 2020, astronomer Jonathan McDowell identified the Qased rocket as deploying a 6U CubeSat after analysing video of the launch provided online by Iranian Military Achievement Media (IMA Media) at https://imadl.ir.

In the video, a close-up of the Qased clearly showed an image of a 6U CubeSat painted on the side. Moreover, the image showed the CubeSat to be "scanning" the Earth – Saudi Arabia and Israel were highlighted – as if to show that it was gathering either imagery or intelligence data.

At the time, the IRGC claimed that the Nour was a military satellite with full imaging capabilities, but by 25 April US Space Command (USSPACECOM) claimed that it was actually a 3U CubeSat with a basic webcam and that it was unlikely to be used for intelligence or imagery collection. A post on



Procitec go2MONITOR software playback shows a pass by the Nour 01 Iranian 'military' satellite on 30 May 2021. The playback depicts a packet burst with raw signal data at the bottom right.

Tony Roper: 1789005

Twitter by General Jay Raymond, first chief of Space Operations for USSPACECOM, also indicated that the CubeSat was tumbling. It is likely – although unknown – that this has been corrected, as many CubeSats tumble after deployment as they knock into each other on exit from the delivery vehicle.

Satellite monitoring

The US North American Aerospace Defense Command (NORAD) assigned the Nour a catalogue number of 45529, and USSPACECOM's claim that it was a 3U CubeSat is still not proven. However, it potentially highlights that the US has more information about this satellite than is being released, suggesting that USSPACECOM can monitor and characterise satellites that are in orbit.

No supporting evidence for the identification of a 3U CubeSat has been released, and any data on the CubeSat could therefore have been obtained before launch from sources within Iran and hence would be subject to public redaction.

The monitoring of satellite communications is popular among amateur radio enthusiasts, and OSINT analysts can easily monitor the ultra-high frequency (UHF) spectrum on the ground with cheap, readily available equipment. The video's revelation of Nour as a CubeSat meant that the downlink data would likely be within the normal bandwidth used by this type of satellite. It would therefore be either in the UHF range of 300 megahertz (MHz) to 3 gigahertz (GHz) or in the S-Band (2–4 GHz) radio spectrum – the most popular bands used by small CubeSat operations.

The components involved with the CubeSat design and construction are cost-effective. For example, only small UHF antennas are needed to transmit data rather than larger high-gain dish antennas associated with higher bandwidths that can be costly to design, take up valuable space on the CubeSat, and potentially fail to deploy once in orbit, therefore rendering the entire mission worthless. For the same reasons of cost-effectiveness, UHF CubeSats are the easiest for OSINT monitoring by amateurs who have an interest in receiving the data sent by the CubeSat.

Scott Chapman, an OSINT analyst based in the eastern United States, investigated whether Nour could be sending data in the UHF. Through online searches, he discovered that the Iranian Communications Regulatory Authority (CRA) had published a chart that depicted all the allocated bandwidths that were to be used for all communication types within

Twitter: 1789003

Astronomer Jonathan McDowell analyses a video released online by Iranian Military Achievement Media (IMA Media) that concerned the launch of Iran's first 'military' satellite, the Nour. The IRGC initially claimed that the Nour was a military satellite with full imaging capabilities.

Iran (available online at https://www.cra.ir/). Although the chart dated back to March 2013, it showed that downlinks from space operations in the UHF band were to be placed between 401 and 402 MHz.

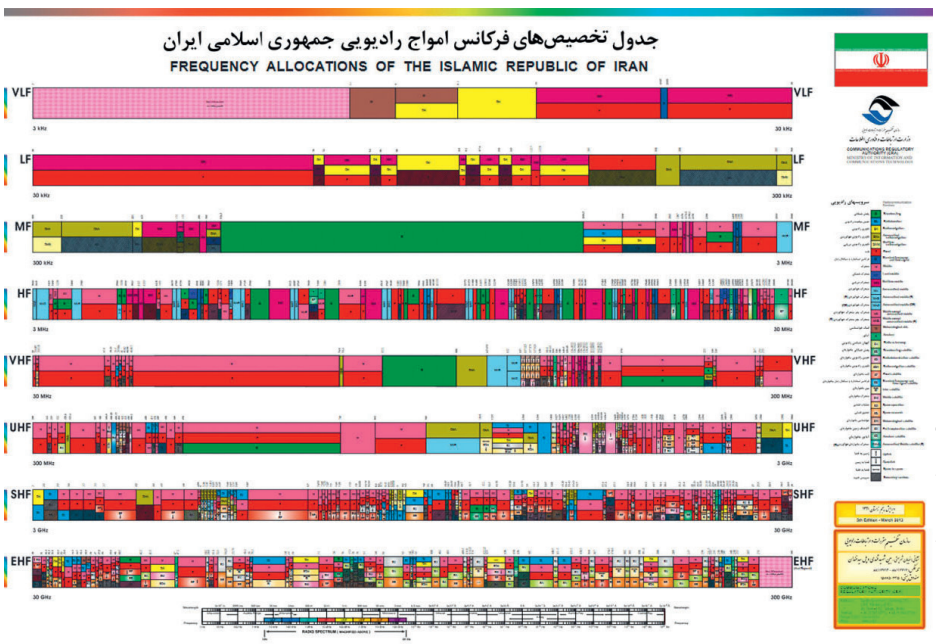
Once the Nour's two-line element set (TLE) – a data format for key orbital elements of space objects – was made available, it was possible for OSINT analysts to add this to satellite tracking software such as WXTrack and Orbitron. This software enables amateurs to track satellites that orbit with antenna rotators, and the software has a functionality that changes software-defined radio (SDR) frequencies to cancel out any doppler effect if a satellite does not have an antenna rotator. Chapman could then calculate passes that would be within range of his location and therefore potentially open to receiving downlink data, and he achieved this in the early morning of 24 April UTC when Nour was identified as emitting on 401.5 MHz.

Analysing transmissions

The downlink data received was in a standard 9600 baud frequency-shift keying (FSK) unencrypted packet form, with each packet being approximately 1.4 seconds in length and sent every 10 seconds. This would generally not be expected for a military satellite transmitting classified data.

Because the format was unencrypted, the packet data could be processed by free open-source software used in amateur radio monitoring (such as Dire Wolf and UZ7HO SoundModem) and available to Chapman. It was clear from the data that it was telemetry information sent in the AX.25 UI frame protocol, a form of data linking used in amateur radio.

Although the telemetry data itself could not be decoded as the key was not available, the first line of each data burst contained an unencrypted source/destination address field that identified the call signs in use. In the case of



Iranian Communications Regulatory Authority (CRA): 1789004

Frequency allocations of the Islamic Republic of Iran via the Iranian Communications Regulatory Authority.

```
330
331  [2021-04-25 02:12:03] ------
332  [2021-04-25 02:12:03] U frame UI: p/f=0, No layer 3 protocol implemented., length = 254
333  [2021-04-25 02:12:03]  dest    EARTH   0 c/r=1 res=3 last=0
334  [2021-04-25 02:12:03]  source  SPACE   0 c/r=0 res=3 last=1
335  [2021-04-25 02:12:03]   000:  8a 82 a4 a8 90 40 e0 a6 a0 82 86 8a 40 61 03 f0  .....@......@a..
336  [2021-04-25 02:12:03]   010:  42 42 00 ee 49 b6 a1 4b ca 8e 78 8d 4a 8f 2f 60  BB..I..K..x.J./`
337  [2021-04-25 02:12:03]   020:  0d fc 14 19 0f 83 15 04 19 02 0c 01 27 10 00 00  ............'...
338  [2021-04-25 02:12:03]   030:  00 00 00 00 02 3c 02 3c 02 3c 01 97 fd 85 02 24  .....<.<.<.....$
339  [2021-04-25 02:12:03]   040:  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
340  [2021-04-25 02:12:03]   050:  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
341  [2021-04-25 02:12:03]   060:  00 01 00 01 00 01 00 00 00 00 00 00 00 00 00 01  ................
342  [2021-04-25 02:12:03]   070:  11 33 e3 ad 03 02 e0 00 58 00 d7 0b c1 07 00 00  .3......X.......
343  [2021-04-25 02:12:03]   080:  00 00 00 00 00 00 00 00 0c 00 00 00 1d 00 00 00  ................
344  [2021-04-25 02:12:03]   090:  00 00 00 00 02 01 00 00 00 00 03 15 16 02 0d 0d  ................
345  [2021-04-25 02:12:03]   0a0:  00 00 00 04 1b 1b 03 15 16 d4 d2 00 15 09 14 0c  ................
346  [2021-04-25 02:12:03]   0b0:  21 12 fd 1a 01 10 03 11 13 10 00 27 19 00 00 00  !..........'....
347  [2021-04-25 02:12:03]   0c0:  00 00 00 00 00 33 19 34 00 18 00 00 01 02 06 69  .....3.4.......i
348  [2021-04-25 02:12:03]   0d0:  00 01 00 00 00 00 00 00 00 00 5f 02 00 00 0d a0  .........._.....
349  [2021-04-25 02:12:03]   0e0:  00 00 00 00 00 00 00 00 00 07 ed 80 00 00 08 47  ...............G
350  [2021-04-25 02:12:03]   0f0:  00 00 08 46 02 1d 00 00 01 15 00 d2 00 4e        ...F.........N
351  [2021-04-25 02:12:03] ------
352
353  [2021-04-25 02:12:13] ------
354  [2021-04-25 02:12:13] U frame UI: p/f=0, No layer 3 protocol implemented., length = 254
355  [2021-04-25 02:12:13]  dest    EARTH   0 c/r=1 res=3 last=0
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Twitter: 1789007

A screenshot from the Twitter account of Scott Chapman on 25 April 2021 at 0212 UTC shows 'decoded' telemetry data from the Iranian Nour satellite, sent as 9600 baud packet bursts. Many lines have similarities that lead to repetitive or nearly repetitive data being transmitted as slight changes occur in the telemetry data.

Nour, it was "from SPACE to EARTH". This address combination had been noted previously in educational CubeSats deployed by institutions such as universities and private enterprises for experiments, and is not uncommon.

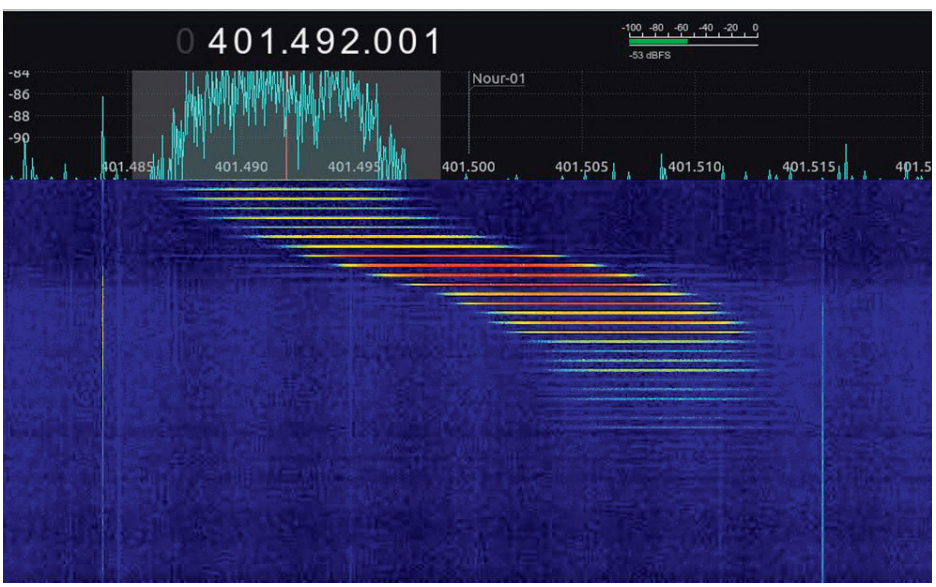
Chapman then used social media to ask for any further reception reports of Nour from other locations around the world. Other amateur satellite observers were subsequently able to produce reports of the same kind.

Telemetry such as that received from Nour is likely to contain data on the health of the CubeSat itself rather than any information that it may have received or scanned, and this would explain the short bursts. Analysis of the raw data shows repetitions at the beginning of nearly every line within each byte sequence, and this alludes to headers for characteristics such as temperature, power, and other data points useful for observing the CubeSat's status from the ground.

However, some amateurs in Europe occasionally observed a full data stream, suggesting that more information than just telemetry was being transmitted. An initial thesis was that the Nour entered a semi-dormant mode that simply transmitted its status while it was transiting out of range of Iran, only beginning to transmit data for analysis on the ground when moving over southern Europe and hence coming into range of Iran. According to Chapman, the data packages transmitted on these occasions did not match those of standard JPG image files associated with CubeSats and therefore were unlikely to contain surveillance imagery obtained while overflying areas of interest to Iran.

Subsequently, Nour data obtained from accessing observations recorded by the Satellite Networked Open Ground Station (SatNOGS) project showed that these data streams did occur elsewhere on the orbit, including over the US. SatNOGS is a satellite ground station network built using free software and open-source hardware by professionals and amateurs around the world. According to its website (https://satnogs.org/), it has more than 260 operational ground stations and approximately a further 140 in testing mode, and it monitors more than 580 satellites using at least 1,140 transmitters.

The European Space Agency has previously used SatNOGS. For instance, the agency



Twitter: 1789006

A screenshot from the Twitter account of OSINT analyst Scott Chapman posted on 25 April 2021 at 0212 UTC shows the Iranian 'military' satellite Nour being received on a software-defined radio with a downlink frequency of 401.5 MHz, although the image shows the doppler effect as the satellite travels in orbit.

used SatNOGS to gain data on its OPS-SAT CubeSat in 2019 when it was initially outside the range of any of its own receivers immediately after being placed in orbit. On 25 April 2021, SatNOGS announced that it had exceeded 4 million observations through the network since its inception in 2014 for the NASA SpaceApps Challenge.

The SatNOGS website also provides plans for antennas, as well as files to produce equipment for ground stations that can be created with 3D printers. Other services include plans for printed circuit boards and assistance to create a full ground station using cheap software-defined radios. The freely available supply of such information and support encourages those interested in satellite monitoring to build their own station, incurring only minimal costs.

Outlook

Although Nour is sending data, this could be for no other reason than test monitoring by a basic ground station at the Shahrud Space Centre. Early rhetoric from the IRGC claimed that Nour would be able to send imagery and other intelligence to Iranian ground stations, but this is clearly not the case. Nevertheless, the launch of Nour does send a message to the West that Iran has become capable of putting a 'military' satellite into orbit and obtaining data from it.

Either on 31 January 2021 or 1 February 2021, the Zuljanah Satellite Launch Vehicle (SLV) was launched into a sub-orbital apogee for testing and telemetry purposes from another launch pad at the Imam Khomeini Spaceport in Semnan province (35.234722, 53.920833). Similar to the Qased rocket used in the Nour launch, Zuljanah uses a transporter erector launcher (TEL) rather than a fixed location for launch and can be set up rapidly if required.

This suggests that Zuljanah could be used for testing intercontintental ballistic missile (ICBM) capabilities rather than for satellite deployment. The Iranian Ministry of Defence has nevertheless stated that Zuljanah will be used for carrying up to 10 20 kg CubeSats into low Earth orbit, or one larger 220 kg satellite, and Nour could be an initial step in such a project, possibly run co-operatively between the MoD and IRGC. The IRGC has proved that it can send a satellite into orbit and keep it operational for more than a year, which implies significant progress after many previous failures.

Iran's claimed ability to make this leap is nevertheless contentious. As part of the investigations by OSINT analysts into the Nour telemetry data, it transpired that the source/destination address field matched that recorded previously in another CubeSat called Painani 1 (NORAD 44365), originally launched from Mahia, New Zealand, on a Rocket Labs Electron 10 on 29 June 2019 on behalf of Mexico's Secretariat of National Defence.

Further investigation by OSINT analysts showed that the Painani 1's subsystem modules were interconnected through a CubeSat Kit Bus (CSK Bus) made by Pumpkin Space Systems, based in San Francisco. Pumpkin Space Systems sells 3U CubeSat kits as part of its product line, and *Janes* has ascertained that one of its previous customers was the US National Reconnaissance Office (NRO). The company also provides components for other CubeSat projects, many of which are aimed at government and educational organisations, including NASA.

It could be coincidental that Nour is sending address data that matches other previously identified examples, but this could also explain the success that the CubeSat has had in remaining in orbit for more than a year. Iran is well known for attempting to copy technology already available and, in the case of Nour, may have successfully done so, including the data that the CubeSat sends. The question then arises of whether the IRGC managed to obtain a CSK Bus from elsewhere, using an unchanged and default source/destination address. ■

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