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V3C: Mobile and compact control centre for small satellites

A suitable ground segment is required for the rapid delivery of small satellites to low-earth orbits in days or hours. The V3C Mobile Compact Control Centre is a small and compact mission operations system that runs on a laptop. Its operational capability has been successfully demonstrated with a satellite of the German Aerospace Centre.

Ground segments for satellite operations are typically set up in mission control centres, where they occupy a dedicated control room and are closely tied to the centre's infrastructure. The ability to move a mission operations system out of a stationary control centre opens us several possible applications such as disaster response, security and defence, decentralised access to scientific missions, and education. Particularly when it comes to security and defence, the ability to quickly identify and respond to threats is made possible by the provision of reconnaissance data in the field by one or more mobile and compact control centres. Such a system can be combined with a traditional control centre for centralised planning and command. In the event of a loss of the primary or backup control centre, such mobile systems represent an additional degree of resilience.

Our research activity has focused on the development of such a system: the V3C Mobile Compact Control Centre, which is shown in Figure 1. It comprises flight-proven multi-mission components that are used for traditional mission operations systems at the German Space Operations Centre (GSOC) of the German Aerospace Centre. Figure 2 provides an overview of the system design. The monitoring and control system is the subsystem that enables the collection, interpretation, and storage of satellite telemetry (TM) as well as the preparation and release of telecommands (TC). The purpose of the mission planning system is the generation of consistent, conflict-free timelines for imaging payloads and satellite bus commanding. It also supports the pre-planning and ordering process for image acquisitions. The flight dynamics system is responsible for computing any information related to satellite orbit position and attitude. Its output is used by the connected ground station for antenna pointing and also serves as input to the mission planning system.

All components are integrated into a single commercial off-the-shelf laptop. This computer acts as a host for a number of virtual machines in which the system components are deployed. By leveraging "infrastructure as code" techniques, hardware provisioning is completely automated, which allows us to quickly roll-out the entire system from scratch. During development, automated provisioning was integrated into continuous integration / continuous deployment pipelines for tight feedback loops. Special care was taken to minimise the number of external interfaces in order to operate the system as autonomously as possible. Only an external ground station connection, a time source and sporadic access to solar flux and Earth rotation data are needed. The effects of the latter have been studied to identify mission constraints.

V3C has been successfully demonstrated in operations of the BIROS satellite of the German Aerospace Centre, which is a 130 kg platform in a polar orbit which hosts infrared and optical imaging payloads. V3C was integrated into the GSOC infrastructure in such a way that it acted as a drop-in replacement for the traditional mission operation system, which remained in stand-by mode in order to resume command in the event of a contingency. The demonstration operations covered the complete use case for image acquisitions. The target area was selected interactively using orbit information derived from satellite telemetry. This imaging request was transformed into a timeline and telecommands. They were uplinked during a ten-minute contact using the Weilheim ground station (see Figure 3). Data collection was performed autonomously by the satellite according to the timeline and downlinked during a following contact over Weilheim. The payload data was processed on the V3C system, resulting in the image shown in Figure 4.

Fig. 1: V3C system on a commercial laptop

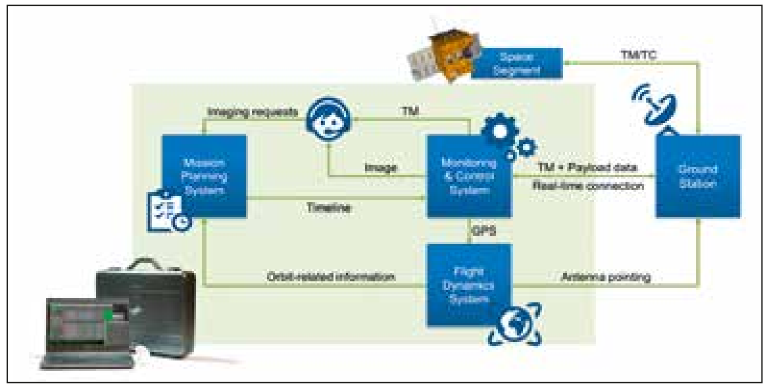

Fig. 2: Overview of the V3C ground segment design

Fig. 3: Ongoing satellite operations using V3C (located at bottom of image)

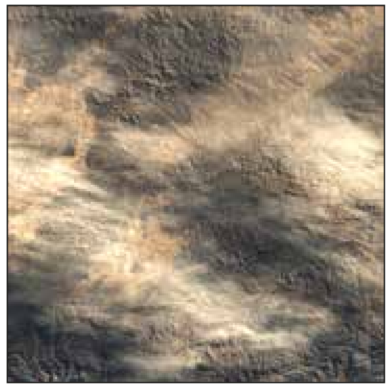

Fig. 4: Image of an area around Truth or Consequences, New Mexico, USA, acquired during the V3C demonstration campaign