Challenge Statement: Earthwork Monitoring From Above
CAN WE REALLY MONITOR FROM ABOVE WITH SATELLITES?

The geotechnical asset base of the mainline UK rail network is an incredibly diverse engineering estate. The asset management of this portfolio is interesting yet challenging. Earthwork asset failures and landslides onto the infrastructure do occur; with an increasing frequency in periods of challenging weather.

Network Rail own and maintain the infrastructure safely to allow operators to run services on time. I am always thinking of ways in which we can improve geotechnical asset management to provide an even safer and more reliable asset.

Organisations frequently get in contact with the latest offering in geotechnical monitoring capabilities; more recently this has been in satellite techniques (i.e. InSAR). The potential benefits of repeatable data to millimetre accuracy is clear. Monitoring a thin linear asset covered in dense vegetation is however a challenging one. It is very different from monitoring the impacts of tunnelling through urban environments or the extraction of natural resources across wide geographical areas.

This pack provides a number of asset failure case studies. Should organisations wish to test their satellite capabilities with real examples this should provide an opportunity to trial / prove capabilities. Personally I remain unsure when satellite technology will be able to provide holistic health-check monitoring or tactical risk mitigation; but the challenge is there!

Please feel free to get in touch with proposals or examples that clearly demonstrate effective capability.

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The potential for utilisation in Network Rail

There is significant potential for future uptake of technology from the space industry if satellite monitoring can actually deliver the results that are often marketed. Currently NR spend approximately £20m per regulatory control period to inspect earthwork assets. Additionally there is up to £20m associated with vegetation clearance to facilitate examiner access.

The vision is to one day remove the basic visual inspection from our earthwork management process – replacing with highly reproducible and repeatable data streams. This would provide heartbeat monitoring across the network to provide a pre-cursor warning to movement for an engineer to then visit site. An objective and highly repeatable data set is key. There is also a desire to remove individuals from working alone across the network on steep slopes.

Further areas of management where NR could exploit emerging improvements in satellite data are listed below.

- Highly frequent monitoring of susceptible earthworks assets (100m in length) to provide confidence in condition whilst awaiting capital investment strengthening works. Already identified ‘hotspots’.
- Monitoring peat wastage where it concerns NR (i.e. Anglia Fenlands).
- Legacy hazards from mining (subsidence and tips / stock-piles).
- Natural landslides along the railway corridor.
- Coastal, estuarine and river defences (CERDS).
- Identifying significant changes of land use adjacent to the railway where there is a potential to cause harm to Network Rail.

Opportunities exist if large data can be turned into intelligence and also dovetailed into the asset inventories and unique asset identifiers.

Case Studies (subsequent pages): - priorities to demonstrate capabilities

1. Failed Embankment @ Leighton Buzzard
2. Washout of Rock Cutting @ Watford
3. Soil Cutting Failure @ Chipping Camden
4. Subsiding Embankments @ Withy Beds
5. Natural Slope Failure @ Eden Brow
6. Coal Authority Tip @ Snowdown
7. Coastal Management @ Folkestone to Dover
8. Third Party Activity @ Hatfield
9. Embankment Failure @ Stonegate
Failed Embankment @ Leighton Buzzard (LNW Route: LEC1 41m 1690)

- Leighton Buzzard embankment failure on 30th January 2016; deterioration possible for a period of time before in a progressive type failure (as high level ballast boards are in place to retain shoulder). Land use change in immediate vicinity also a concern with stockpile of material that had grown adjacent to the rail corridor – starting in July 2012.

- Could satellite monitoring have foreseen this? How did earth assets ½ mile in either direction compare to the failed asset? Additionally could the growing stockpile adjacent to the railway have been identified?

- Easting: 490,080 Northing: 227,439 (embankment failure) & E: 490,156 N: 227,485 (stockpile growth)
Washout of Rock Cutting @ Watford (LNW Route: LEC1 19.0990 Up)

- Significant safety event following 70mm of rain in a 3 hour period. Washout of cutting slope from surface water overtopping cutting crest. Train subsequently derailed on approach into the tunnel. Failure on 16th September 2016.
- Potential change of land profile away from the railway may have concentrated water towards the railway. It is the change in land profile that is of interest here and whether this could have been identified.
- Could satellite monitoring have foreseen the change in land topography adjacent to and away from the area of the failure in land not owned by Network Rail?
- Easting: 508,877 Northing: 199,990 (NE of tunnel portal)
Soil Cutting Failure @ Chipping Camden (Western Route: OWW 98m 13ch Up)

- Significant failure of the cutting adjacent to the tunnel portal.
- Slope movement commenced in April 2013, with predominant movement taking place in April to July. Notable tension cracks, back-scar and toe bulging as slope relaxed and progressively failed.
- Reactive remediation took place and substantial excavation of re-grade work was completed by end of November 2013; by which point slope monitoring showed rates of movement had slowed.
- Could satellite monitoring have foreseen this? How did earth assets ½ mile in either direction compare to failed asset?
- Easting: 415,913 Northing: 241,405 (north-east side of tunnel portal)
Subsiding Embankments @ Withy Beds (Wessex Route: NGL 20.0700)

- Consisting of London Clay the embankment is susceptible to moisture changes and the original profile continues to relax as the material adjusts and moves to find its natural angle of repose. Major interventions have taken place historically (1960s) and in 2007/08 and 2011/12. Sheet piling used to arrest lateral spread of embankment.

- Embankment has been suffering ongoing deterioration for a number of years. Site continues to require high maintenance strategy to keep track quality; fixing the symptoms rather than root cause. Last rough ride reported on 19\textsuperscript{th} December 2015.

- Could satellite monitoring be used to visualise ongoing lateral embankment spread? How do the earth assets ½ mile in either direction compare to the location of current concern? Focus on the lateral spread along the toe of the slope (near to NR fence line) as crest settlement likely to be masked by track maintenance works.

- Easting: 510,957 Northing: 156,759
Natural Slope Failure @ Eden Brow  (LNW Route: SAC 300m 0660yds Down)

- Natural slope supporting the railway failed during the original railway construction. Historical solution consisted of toe weighting at the bottom of the slope adjacent to the river.
- King post wall installed at track level in early 2014 to provide short to medium term solution whilst the extent of a perceived larger problem was investigated.
- Wettest December on record and second wettest winter on record triggering factors to large scale re-activation. Swollen river levels eroded base of natural slope and exacerbated rate of movement. High level wall started to deteriorate and misalign as a result of ground movement. Track movement and wider geotechnical concerns resulted in line closure on 9th February 2016.
- Line closure advised to be at least 6 months whilst a significant engineering challenge is investigated and implemented,
- Could satellite monitoring have foreseen this? How did earth assets ½ mile in either direction compare to failed asset?
- Easting: 349,832 Northing: 549,431 (north-east side of railway)
Coal Authority Tip @ Snowdown (Kent Route)

- Disused Coal Authority workings and tips adjacent to railway infrastructure
- Could satellite monitoring be used to provide assurances that these legacy areas adjacent to our infrastructure are stable and advise if movements start to occur.
- Easting: 624,700 Northing: 151,000
Coastal Management @ Folkestone to Dover (Kent Route)

- One of the largest active landslides in NW Europe. Folkestone to Dover railway runs through the warren between Martello Tunnel and Abbotscliff Tunnel. Significant history of major ground movement and cliff falls. Specialist management plan in plan.
- During the wettest winter on record (13/14) deep seated movement accelerated, causing damage to sea defences and settlement to the track in locations where the slip plane passed beneath. Problems from January to April 2014.
- Substantial operational restrictions on line-speed deployed and significant track works required to restore alignment and level.
- Could satellite monitoring have foreseen this? How did earth assets ½ mile in either direction compare to failed asset?
- Key areas:
  - Slip plane intersecting railway (next to TP hut). Easting: 625,088 Northing: 138,020
  - Horsehead Point / Concrete sea defences on foreshore. Easting: 625,761 Northing: 138,205
  - Old Dover Road: Easting: 625,987 Northing: 138,606
  - Shakespeare Beach: Sea wall damage and beach level change in Dec 2015. Easting: 630,865 Northing: 139,974
**Third Party Activity @ Hatfield (LNE Route: DOW 7m 25ch)**

- Catastrophic deep seated failure of a third party spoil heap adjacent to the railway. On 9\(^{th}\) February 2013 train driver noticed a track defect when passing Hatfield Colliery. Three lines were closed on the 11\(^{th}\) Feb and the fourth line was closed on the 12\(^{th}\).
- **Could satellite monitoring have foreseen this? How did earth assets \(\frac{1}{2}\) mile in either direction compare to failed asset?**
- Easting: 466,351 Northing: 411,770 (north-side of railway)
**Embankment Failure @ Stonegate (Kent Route: TTH 43m 42ch Down)**

- Catastrophic failure of the embankment during the wettest winter on record (2013/14); failing on the 09/02/2014 after staged deployment of ever increasing operational mitigations, following a rough ride, and ultimate line closure.
- Notable deterioration in track quality over time; on radar of Geotechnical engineers from early 2013.
- Ground investigation planned for 2014 but asset failed before borehole instrumentation installed to monitor. Notable geomorphological features indicated a slow moving deep seated failure had been taking place for a number of years.
- Toe drainage improvement works undertaken in summer 2013 to manage / reduce risk during 3 year project.
- Could satellite monitoring have foreseen this? How did earth assets ½ mile in either direction compare to failed asset?
- Easting: 565,559 Northing: 127,529 (north-side of railway)