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# Optimizing fact-finding in incident investigation and analysis using Tripod TRACK

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## Abstract

Incident investigation and analysis is an essential part in identification of risks and managing the business process. The quality of the investigation and analysis determines on what level remedial actions can take place. The better the investigation and analysis, the more one finds the systemic causes of incidents. By identifying and remedying these systemic causes, entire classes of incidents can be prevented.

The Tripod theory has been used to develop the incident analysis method Tripod Beta. This tool is seen as the state-of-the-art methods to analyse incidents. The method itself however is not explicitly designed for the fact-finding-phase, although the Tripod Framework gives a clear direction and supports this phase.

This paper describes a new tool in the Tripod family: TRACK. TRACK facilitates the process of fact-finding and enables the investigator to get away from the "what happened" to "what made it happen". Results show that using TRACK increases the consistency and objectivity of the investigation, and forces the investigator to dig deeper than with any other tool available.

## Introduction

Since the publication of Human Error in 1990[1] a consistent trend in the interest in the contribution of human error to industrial accidents can be noticed. The common factor in this trend is the theory that prevention of human error is most effectively gained by controlling the working environment instead of focusing at the individual who 'failed'. [2], [3] Safety does not, as many experts believe, depend on the number of sprinklers and hydrants installed, but a high proportion of accidents and catastrophes are the obvious result of management error. [4] According to Rasmussen [5] accidents are the result of lack of control: 'A closer look at major accidents indicates that the observed coincidence of multiple errors cannot be explained by a stochastic coincidence of independent events. Accidents are more likely caused by a systematic migration toward accidents by an organization operating in an aggressive, competitive environment. [..] Safety is a control problem.'

To prevent human error a range of techniques are available, some more effective than others. Initiatives like Unsafe Act Auditing, Qualitative Risk Assessment and Technical Safety Auditing are in many companies applied to increase safety. These techniques may be necessary but are not yet sufficient to further decrease the number of accidents.

Essential in trying to improve the safety state of individuals is to acquire insight into the situations that lead to accidents and how those specific situations can be avoided. These factors are not only present at the work floor but also at other supervisory and managerial levels. The most successful ones focus on the managerial responsibility in identification and elimination of adverse conditions at the workplace. Due to the complexity of dynamic organizations, management cannot develop fail-safe long-term solutions. They should therefore not focus on the complete elimination of human error and the corresponding dynamics of human behaviour by enforcing strict compliance with procedures but on the soundness of their organization. They have to control the processes they initiate to remedy deficiencies in the structure of the organization.

Concepts can be used from complexity theory. This theory provides a way of thinking about the successes and failures of organizations. This part will conclude that, ultimately, it is not the outcome of the process that should be subject to managerial control but the process itself. Central to complexity theory are some core-ideas: non-linearity, self-organization and emergence. Findings from complexity theory suggest that it is impossible to predict the future behaviour of complex dynamic systems. This is not what most managers believe: their common assumption is that part of their job is to decide where the organization

is going and to take decisions designed to get there. According to complexity theory this is a dangerous delusion. Management, afflicted by increasing information overload and complexity, can react by becoming quite intolerant of ambiguity. Factors, targets, organizational structures all need to be nailed down. Uncertainty is ignored or denied. The management task is seen to be the enunciation of mission, the determination of strategy and the elimination of deviation.

Traditionally, in the 'ideal' organization there is a Chief Executive Officer (CEO) presiding over a cohesive management team with a vision or strategic intent supported by a common culture. The organization should stick to its core business and competencies build on its strengths and keep its eyes focused on the bottom line. This top-down strategic initiatives approach is a recipe for organizational disaster. Even the US army is evolving from just following orders. Since the Gulf War a practice called 'directional intent' has been used in which commanders set up units with broad objectives, and the units make decisions semi-autonomously and learn as much from each other as from central command. Leaders and managers should aim at developing conditions, which allow self-organizing behaviour to flourish and blossom. They need to create adaptive organizations with flexible structures, skills, processes and information flows, rather than hierarchically imposing change.

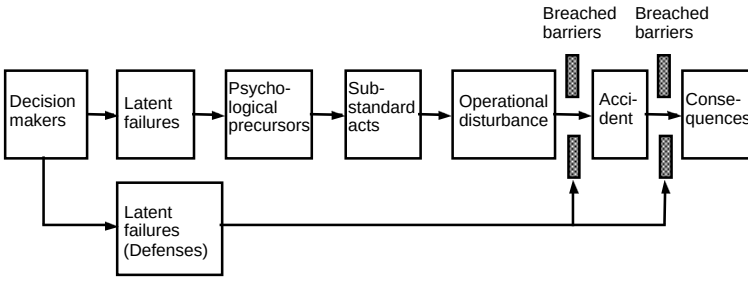
It is essential to manage the strategic fundamentals related to the soundness of an organization itself. Even when all the relevant factors determining the soundness of an organization are identified, taking the best decision is a difficult, even bewildering problem. This paper focuses on taking take the most effective decisions and developing an adequate leadership style based on the parameters that determine the soundness of the corporate immune system.

## Tripod: the concept

To determine the soundness of the corporate immune system, the Tripod model can be used. Tripod has been developed at Leiden and Manchester University. It started as a research project investigating ways of preventing human error initiated by the Royal Dutch / Shell Group in 1986. The project resulted into an instrument that is now applied in settings ranging from the Nuclear Energy Authority in the U.K., chemical companies like DSM, Unilever and Shell Chemicals, oil and gas production on the North Sea, the Traffic Control and Safety Units of the Dutch National Railway Company. [6]

According to the Tripod model (Figure 1) accidents are always caused by one (or more) substandard act(s). Not all substandard acts result in accidents. What an organization needs to prevent are the 'operational disturbances' that precede accidents and incidents. [7] If disturbances of the desired way of operating still take place, the organization has to put barriers in place to prevent these disturbances from turning into an accident or incident. When they are breached or not present at all, an accident or incident occurs. An accident is seen as an operational disturbance followed by its consequences. In between the operational disturbance and the accident barriers are (possibly) located, but they failed, were breached, or circumvented.

**Figure 1 the Tripod model of accident causation**




Substandard acts are by no means random events. They have their immediate origins in psychological states of mind, or patterns of reasoning, which are called psychological precursors. In turn these psychological precursors are elicited by the physical and organizational working environment of people. This can be the way the work is organized, the way the equipment and tools are designed, but also the ergonomics of the work place. [8] Environmental conditions that cause the psychological precursors of substandard acts are called latent failures. Latent, because they are present long time before a specific substandard act or accident has occurred and remain hidden without a specific local trigger. These latent failures are usually the result of fallible decisions made by the upper level in systems, such as decision-makers, legislators, designers, managers, and inspectors. The Tripod theory recognizes 11 parameters that are critical to the level of control in an organization. These determinants are called Basic Risk Factors (BRFs). The level of control of these BRFs is indicative for the quality of the management of all business/production processes in different types of organization (Table 1 and Table 2).

**Table 1 the eleven BRFs**

| Specific for a branch | Generic |
|---|---|
| Design (DE) | Procedures (PR) |
| Hardware (HW) | Training (TR) |
| Maintenance (MM) | Communication (CO) |
| Housekeeping (HK) | Incompatible Goals (IG) |
| Error Enforcing Conditions (EC) | Organization (OR) |
| Defences (DF) | |

**Table 2 psychological precursors and substandard acts[9]**

**Psychological Precursors**

- Double-capture slip
- Omissions following slips and lapses
- Reduced intentionality mistakes
- Perceptual confusions
- Interface errors mistakes
- Omissions
- Repetitions
- Reversals
- First exceptions
- Countersigns and violations
- management non signs
- Information overload violations
- Rule strength
- General rules
- Redundancy
- Rigidity
- Encoding deficiencies
- Wrong rules
- Inelegant rules
- Inadvisable rules
- Confirmation bias
- Salience bias
- Framing bias
- Overconfidence
- Representative heuristic
- Available heuristic
- As if" heuristic

**Substandard acts**

- Skill-based slips and lapses
- Rule-based mistakes
- Knowledge-based mistakes
- Routine violations
- Violations for kicks
- Necessary violations
- Exceptional violations

Identification of latent failures, the hidden failures in systems, can be done in a pro-active and re-active manner. This paper will focus on the additive value of TRACK in the process of incident investigation and analysis, a reactive process. Therefore, next section will describe the reactive instrument Tripod Beta.

## Tripod Beta

Based on the Tripod model of accident causation, incidents can be analysed. Tripod Beta starts with an incident that has happened. This can be any operational disturbance: with or without consequences, with (a potential) damage for instance in the field of safety, health, environment, quality, or corporate reputation.

The final event of the incident will act as the main event Tripod Beta. For this event, the Target and the Hazard will have to be defined. The Target is the object that was harmed by the Hazard, and can for instance be people, assets, products, quality and reputation. The Hazard is the energy that caused the harm to the Target. On their turn, the state of Hazards and Targets can be a result of previous events as well, being an event on its own. This way, the chain of events resulting in the incident can be identified. An example of a Tripod Beta event-chain is shown in Figure 2.

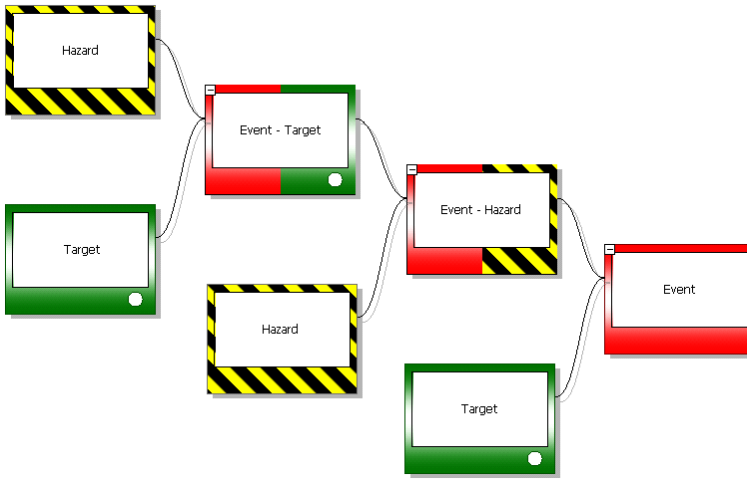



**Figure 2 Example of a Tripod Beta event-chain**

According to Tripod Model of accident causation, events can be prevented by having adequate barriers in place. A barrier controlling the hazard, is called a control, a barrier (partly) defending the target, is called a defence. A control can for instance be insulation (when the Hazard is hot pipe work); a defence can be wearing gloves (when the target is an operator). Other barriers can be for example effective lock out and tag out, effective access limits, using life saving appliances, as well as following the right procedures, and adequate training. Barriers can be either effective, therewith preventing the event from happening, or they can be missing, failed/breached or inadequate thus causing the event to happen. When the event has happened, each trio of Hazard, Target and Event has one or more missing, failed/breached or inadequate barriers (see also Figure 3).

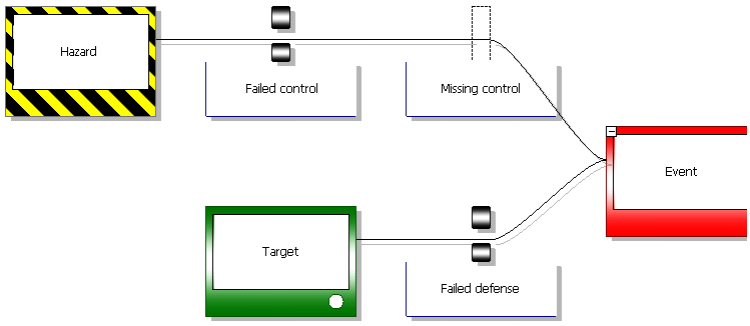



**Figure 4 HET-trio with barriers**

Incident investigation and analysis must reveal what have made the barriers been missing, failed or inadequate. In most cases something directly caused the barrier to fail. These direct causes are called Active Failures in Tripod Beta, and include both substandard (unsafe) acts by people and technical failures. Examples of active failures are violating procedures, making mistakes in operating

routines, misinterpretation of signals, using inappropriate tools, bypassing process steps and corrosion in controls.

These active failures are more likely to occur in a sub-optimal working environment. This suboptimal working environment, including organizational, physical and psychological system states, encourage or influence psychological precursors, which on its turn will encourage or influence the commission on an active failure. The perception that shortcuts are encouraged, an institutional high overtime, uncomfortable working conditions, and reduced manning / skill levels are all examples of preconditions.

Preconditions, which can be present in an organization for a long period of time without causing active failures leading to incidents, are caused by hidden failures in the system: the latent failures. Latent failures are a result of inadequate management decisions and are the targets for improvement. Imbalanced production/maintenance budgets, downsizing/de-skilling without change control, inadequate competence standards/training and inherently deficient procedures are examples of latent failures. An example of a failed barrier and its causal paths can be found in Figure 5.

The final result of a Tripod Beta analysis is a Tripod Beta Diagram representing what happened and what made it happen. Based on the findings in the tree, a report can be written (or generated using the software) , consisting relevant facts like employees, assets and investigation team members involved, a risk matrix, and proposed short-term and long-term actions. Short-term actions are direct actions based on missing, failed or inadequate barriers. Long-term actions are measures based on the latent failures and therefore taken on system level. These actions are more time- and effort consuming but far more sustainable and effective in risk management and preventing incidents and accidents.

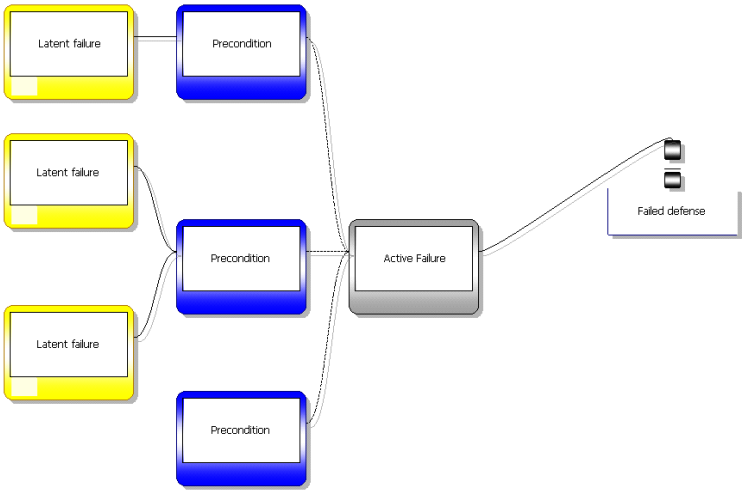



**Figure 6 Failed barrier with causal paths**

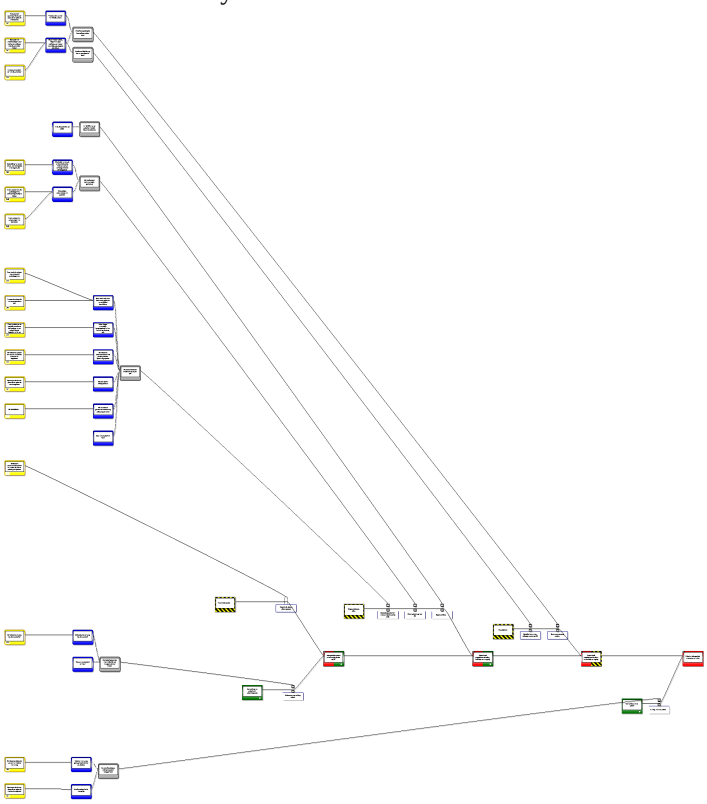


**Figure 7 Example of a complete Tripod Beta Diagram**

## Incident Investigation and Analysis

The Tripod theory states that in order to manage risks, the latent failures in an organisation should be identified and remedied. As has been shown, the strength of Tripod Beta is to guide and structure the analysis of incidents. However, this analysis should be fed with information from investigation.

Traditionally, investigation starts with identifying an incident occurred and the accompanying necessary actions like creating a safe situation, informing the right persons, and deciding if investigation and analysis will be conducted. If the incident will be investigated more in depth, an investigation team will be formed, action plans made, and actions and responsibilities assigned. In most cases, this main assignment of this team is to answer the questions “what happened” and “what do we need to change”. Not always there is sufficient emphasis in this team to retrieve the latent failures, as Tripod Beta uses for its analysis. Several organisations see investigation and analysis as separate processes. This means that they finish up the investigation process and then start with the analysis process. This way, additional questions raised during analysis will not be answered and accepted as unknown matters.

However, incident investigation and analysis should be an iterative process. The Tripod model of accident causation should guide the investigation process in order to retrieve the latent failures. Based on facts found during investigation, the analysis can be commenced. This initial analysis will reveal new questions, which has to be fed into

the investigation process. This way, investigation and analysis is conducted iteratively.

To facilitate this iterative investigation process, and to ensure that it is focused on retrieving latent failures in the format Tripod Beta need them for analysis, TRACK has been developed.

## TRACK

TRACK facilitates the investigation process (fact-finding & evidence gathering) by enabling the investigator to get away from the "what happened" and “how it happened” to "what made it happen".

Based on over 500 incident and accident investigations, preconditions influencing psychological precursors (that stimulate human error) have been identified. Furthermore, the latent failures responsible for these preconditions have established. This research forms the fundaments for TRACK.

TRACK contains guidance to retrieve possible preconditions and latent failures. It consists of a leads-to questionnaire (Table 3), with questions indicative of existing preconditions, and a caused-by questionnaire (Table 4), consisting of questions indicative of existing latent failures. The questionnaires are structured using the BRF framework.

**Table 3 Leads-to sample questions**

- Was there equipment that required an improvised way of operating?
- Were the installations, tools or equipment dirty?
- Was it difficult or impossible to get hold of a copy of existing procedures?
- Were there employees who needed excessive supervision or instruction?
- Were there an excessive number of poorly trained people involved in performing a job?
- Was any information misunderstood or incorrectly interpreted?
- Was information about potential hazards not communicated to the relevant people?
- Were there signs of haste or corner cutting or were steps in a procedure or routine ignored?
- Were the emergency or evacuation planning or procedures not available, not used or inadequate?

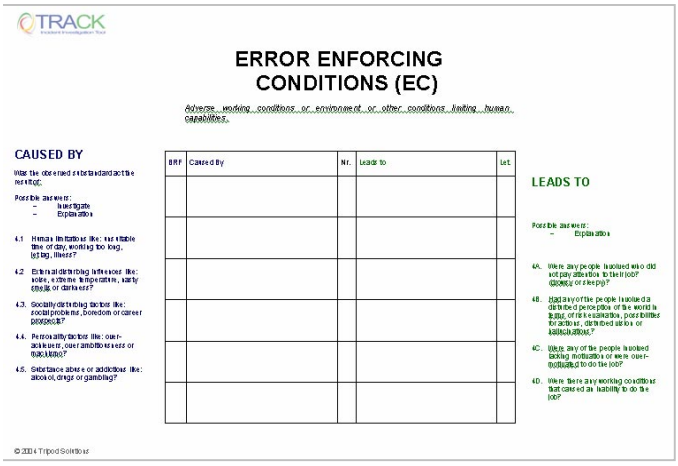
**Table 4 Caused-By sample questions**

- No adequate user-designer communication during or after the design phase?
- Inappropriate selection of equipment to do the job (Quality, wrong sizes or strength)?
- Inadequate planning, controlling, execution or recording of maintenance of the equipment?
- Absent or inadequate manuals or descriptions of the equipment?
- Human limitations like: unsuitable time of day, working too long, jet lag, illness?
- Inadequate corporate policy, lack of management commitment to housekeeping?
- No assessment of the effectivity of training programs?
- Information loss or overload because communication structure is not used or mis-used?
- Conflicts between individual priorities and optimal working routines?

TRACK can be used in different moments in time during the investigation and analysis process. First of all, it can be used up front as guidance for initial investigation. During the evidence gathering, like visiting the incident location, checking papers, manuals and procedures, and interviewing people, the TRACK questions can be used to look for the relevant facts. For instance, when preparing the interviews, TRACK questions can be of guidance to conduct more complete investigation. Using TRACK at this moment in time, means trying to get an answer on all questions in the leads-to questionnaire, being YES plus a specification of the fact found, NO or INVESTIGATE. When a “YES + specification” has been given, the caused-by questionnaire gives options of possible latent failures that could be responsible for the precondition that was found. Working through the complete TRACK questionnaire in this stage, will make the investigation more complete and less sensitive to investigators hobbyhorses, and will redirect the focus from the “what happened” to “what made it happen”. Mature organisations might even decide not to conduct a Tripod Beta analysis anymore, since TRACK has revealed the latent failures to be remedied already. However, most organisations would like to see the TRACK results, the “what made it happen”, visually linked to the “what happened” and “how it happened”. This is done using TRACK during the analysis phase.

Using TRACK during the analysis phase is the second moment where TRACK can be used. When the HET-trio’s have been identified, the missing, failed and inadequate barriers have been determined, and the substandard acts/active failures have been revealed, the leads-to and caused-by questions can structure the search for preconditions and latent failures. The more pure way to use TRACK is by taking the facts found with TRACK during the investigation phase, and use these as the preconditions and latent failures to be connected to the active failures and barriers identified with Tripod Beta. This way, investigation comes from the two ends of the incident causation model: from both the latent failures in the organisation as well as from the consequences they have resulted in. Alternatively, TRACK can be used in this phase for the first time, to identify preconditions and latent

failures for specific active failures. Based on the active failure identified, the investigater goes through the descriptions of the Basic Risk Factors, screening in which factor the precondition and latent failure is most likely to be found, and then going to the applicable leads-to / caused-by questions. For the most objective and complete investigation, the use of TRACK in the first phase of investigation is recommended.




| BRF | Caused By | Nr. | Leads to | Let. |
|---|---|---|---|---|
| PR | The filing system of procedures was inadequate: no system to decide where procedures were to be filed (on/offshore) (latent failure) | 6.3 | The operator offshore did not use the applicable procedure (Active failure) because it was impossible to get a hold on the existing procedures (which were onshore) (Precondition) | 6C |
| PR | ? | | Too many procedures? Investigate | 6D |

**Figure 8 Examples of leads-to /caused-by answering sheet**

To determine the added value of TRACK to the use of Tripod Beta, several incident have been analysed seperately with both Tripod Beta and TRACK. First, a trained Tripod Beta analysed four incidents with Tripod Beta. Then, the Tripod Beta analyst was trained in the use of TRACK, and investigated the same incidents with TRACK. Based on the differences found in the results of the two instruments, the added value of TRACK to Tripod Beta could be decided.

Based on this research it can be conclude that Tripod Beta not sufficiently facilitates in retrieving the real latent failures. Over 40% of the latent failures specified in the Tripod Beta, are actually just preconditions or even active failures. The analyst specifies these as being a latent failure and there is no control to defend him from doing so. TRACK however, is able to identify that the analsyis is not thourough enough, and the latent failure still has to be identified. TRACK is able to inform the investigator his investigation does not reach the true latent failure yet.

Another difference is the categorization of latent failures in Basic Risk Factors. Tripod Beta does not structure the preconditions and latent failures to a Basic Risk Factor as TRACK does. In Tripod Beta, the Basic Risk Factors are decided by the analyst, using his experience. TRACK categorizes the Basic Risk Factors based on both the preconditions ans the latent failure and does not use the expertise of the analyst. This results in a lesser diversity of the Basic Risk Factors used in Tripod Beta compared to TRACK. Based on the availability-heursitics, which states that people always think first of the matters most used and thereby first avalaible in their mind, this can be explained. Tripod Beta analysist will have a tendency to think of their hobbyhorses first, and might forget about the other Basic Risk Factors. TRACK prevents this, by categorizing the latent failures for them.

## Conclusion

TRACK facilitates the process of fact-finding and enables the investigator to get away from the "what happened" to "what made it happen". TRACK increases the consistency and objectivity of the investigation, and forces the investigator to dig deeper than with any other tool available. TRACK has an added value to Tripod Beta.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