

**Regulation under Uncertainty:
The Co-evolution of Industry and Regulation in the Norwegian
Offshore
Gas and Oil Industry**

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Abstract

As production and design disintegrate and become more collaborative, involving dynamic relations between customers and firms supplying complex sub-systems and service, products and production methods become more innovative but also more hazardous. The inadvertent co-production of latent hazards by independent firms is forcing firms and regulators to address more directly than before the problem of uncertainty: the inability to anticipate, much less assign a probability to future states of the world. Under uncertainty neither the regulator nor the regulated firms knows what needs to be done. The regulator must induce firms' to systematically canvas their practices and identify potential hazards. But recognizing the fallibility of all such efforts, the regulator must further foster the institutionalization of incident or event reporting procedures: systems to register failures in products or production processes that could be precursors to catastrophe; to trace out and correct their root causes; to alert others in similar situations to the potential hazard; and to ensure that countermeasures to ensure the safety of current operations are taken and the design requirements for the next generation of the implicated components or installations updated

accordingly. In this essay we look closely at developments in the Norwegian offshore oil and gas industry and its regulator, the Petroleum Safety Authority (PSA) to better understand the co-evolution of vertically disintegrated industry and new forms of incident reporting based regulation.

Key Words: Incident Reporting, Meta Regulation, Norway, Oil and Gas Industry, Uncertainty

1. Introduction

As production and design disintegrate and become more collaborative, involving dynamic relations between customers and firms supplying complex sub-systems and service, products and production methods become more innovative but also more hazardous. Independent suppliers learn rapidly from pooled experience with a wide range of customers; close cooperation between these competent suppliers and final producers generates further innovation through interactive improvement in the designs of each (Herrigel 2010 chs 5-7; Gilson et al 2009). Creative collaboration of this kind, however, also introduces hidden hazards. To take recent examples: Defective airbags supplied by a leading maker to a number of auto companies exploded over a period of years, most frequently in humid environments, with lethal results. Early versions of an innovative air bag supplied to General Motors functioned as intended, but interacted in unexpected ways, again over a period of years, with faulty ignition switches, so that the airbags were deactivated just as crashes occurred. Pathogens periodically enter global food supply chains and then propagate widely as adulterated foodstuffs are incorporated into diverse batches and the processing equipment becomes contaminated. Communication breakdowns between energy operating companies, drilling rig contractors and oil-field services suppliers have been implicated in offshore catastrophes such as the explosion and sinking of the Deepwater Horizon platform. The Boeing 787 Dreamliner fleet was grounded in its first service year by problems originating in a faulty lithium-ion battery supplied by a Japanese manufacturer.

The inadvertent co-production of latent hazards by independent firms is forcing firms and regulators to address more directly than before the problem of uncertainty: the inability to anticipate, much less assign a probability to future states of the world. Traditionally regulation has been an information asymmetry problem: Firms know more than regulators about risks generated and associated mitigation costs, and have incentives to strategically use their superior information to frustrate costly supervision. The regulator's task is to elicit from firms the information necessary to establish public regarding but economically feasible standards and rules, but not at the price of "capture" or ceding regulatory control to its addressee.

Under uncertainty, however, neither the regulator nor the regulated firms knows what needs to be done. The regulatory problem is to organize and supervise joint investigation by firms of emergent risks and respond to them before they cause harm. More exactly, the regulator must induce firms' to systematically canvas their practices and identify potential hazards: for example, by requiring firms to present plans specifying the risks of proposed operations; how those risks will be mitigated; the tests by which the mitigation's effectiveness will be verified; and the methods for recording test results.

But recognizing the fallibility of all such efforts, the second regulatory task is to foster the institutionalization of incident or event reporting procedures: systems to register failures in products or production processes that could be precursors to catastrophe; to trace out and correct their root causes; to alert others in similar situations to the potential hazard; and to ensure that countermeasures to ensure the safety of current operations are taken and the design requirements for the next generation of the implicated components or installations updated accordingly. We will call such two-part systems of regulation under uncertainty recursive or—drawing on American Pragmatism—experimentalist—because they continuously revise initial and inevitably incomplete understandings of hazards in light of shortcomings revealed by the efforts to address them (Sabel and Simon 2011 and Sabel and Zeitlin 2008).

Some regulatory systems with different mixes of these components emerged in the closing decades of the last century. In U.S. nuclear power safety, for example, plants must meet demanding licensing requirements. Once in operation they must report all potentially dangerous operating events, ranging from unexpected equipment deterioration to power generation disruptions to the Nuclear Regulatory Commission (NRC). The NRC evaluates the reports and alerts all operators to the possibility of the same or analogous hazards. Responses to such notices are evaluated by frequent peer reviews (Rees 2009 p 23-50; U.S. GAO - Nuclear Regulation 1991; Morrow et al 2014). Following the explosion in 1988 on the Piper Alpha platform—the worst offshore disaster to date, with a loss of 167 lives—and as part of a general shift away from uniform, prescriptive regulation, the British regulatory authorities require energy companies to submit, and update every five years an installation-specific “safety case” detailing methods for controlling routine operational risks as well as those associated with changes in goals or methods or dangerous failures (Inge 2007).

But such regulatory systems long seemed to be exceptional responses to distinct and manifestly hazardous technological constraints: complex, continuous process operations with interdependent subsystems that transmit disruptions rapidly, often in unforeseen and self re-enforcing ways, with —absent special precautions—potentially catastrophic results for human operators, bystanders and the environment. What is novel in developments since the turn of the millennium is the growing realization by both firms and regulators that rapid innovation through collaborative production diffuses much more broadly the kinds of uncertainty formerly associated with a particular class of technology and that incident reporting systems are the foundation of an effective response.

Here are some examples: The US Department of Agriculture organized pilot programs in the mid 1990s in which U.S. slaughter houses undertook a hazard analysis of the critical control points (HACCPs) at which pathogens could enter the production process, and proposed and tested methods of avoiding or mitigating those risks. Outbreaks of foodborne illness vectored by leafy greens (especially

dangerous because likely to be eaten raw) led California wholesalers to create in 2006 a regime—contractual, but enforced by a state inspectorate—requiring growers to apply HACCP methods on their farms. The Food Safety Modernization Act of 2010 codified and extended this regime to many more products under the jurisdiction of the Food and Drug Administration (FDA). But slow adjustment by the federal inspectorate in slaughterhouses, and foot dragging by firms has rendered implementation halting and at times ineffective (GAO 2013). In the EU convergent developments, again prompted by crisis (the outbreak of mad cow disease, among others), and again involving the interaction of administrative action, legislation and private standards, led to the de facto introduction of HACCP requirements in the early 2000s (Sabel and Simon 2011; Humphrey 2012).

Beginning in 1997, in response to series of accidents, the Federal Aviation Agency (FAA) and the commercial US air carriers agreed on an Air Safety Action Program (ASAP). Under ASAP airline employees report, with assurance of lenient treatment, deviations from standard operating procedures that may violate rules but are almost surely unobservable by either upper level management or the regulator. An event review committee (ERC), consisting of representatives of the carrier, the FAA and the reporting employee's union decide corrective action by consensus. In case of deadlock the FAA representative decides. Each carrier in the program has a continuing analysis and surveillance system (CASS): a team which combines the carrier's ASAP reports with internal audits and other sources to spot alarming anomalies in operations and prioritize remedies. The FAA uses ASAP and CASS reports to monitor the carrier's performance (Mills and Reiss 2013).

Between 2004 and 2007 serious incidents revealed that the FDA was unable to capture information on the adverse effects of drugs it had already approved for use, and lacked authority to respond to warnings from foreign counterparts. An authoritative review (Stratton et al 2007) found that increased pressures and possibilities for innovation, combined with the inherent limits of controlled efficacy and safety tests-- trial periods too short to detect long-term effects; exclusion of persons with co-morbidities typical of the eventual patient population; impossibility of sampling ethnic or other minorities that might respond idiosyncratically—required improved techniques for predicting drug-related hazards, and enhanced authority to operate a post-approval surveillance system. The Food and Drug Administration Amendment Act, enacted in 2007, authorizes the FDA to require a drug producer to conduct a post-approval study or trial to evaluate the extent of known risks, to assess preliminary indications of serious risks, or to use available data to identify previously unknown risks (Pub. L. No. 110-85, § 905(c), 121 Stat. 949). But despite substantial progress in meshing the units monitoring pre- and post-approval (U.S. F.D.A. 2012; U.S.F.D.A. Center for Drug Evaluation and Research 2012), there are conspicuous gaps in the reporting system and, as in food safety, worrisome delays in generalizing pilot project results into new institutional routines (Chen and Yang (2013): 193-213).

In auto safety the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act, passed in 2000 in response to fatalities caused by interactions between a faulty car design and certain tires, lays the foundation for an incident reporting system by requiring manufactures to notify the National Highway Safety Transportation Agency (NHTSA) of product defects as well as injuries or deaths involving their products (49 U.S.C. §§ 30101-30170). The consent decree between NHTSA and GM, in which the latter agrees to report monthly to the former on efforts to eliminate the faults in its internal error detection systems that delayed (for a decade) identification of the air bag/ignition switch interaction is from this year (NHTSA 2014).

Finally, the British Financial Conduct Agency, responsible for overseeing the consumer protection in financial markets, notes in recent guidance that the product originators and their distributors will often be linked as suppliers and buyers in a supply chain. The originator “should have in place systems and controls to manage adequately the risks posed by product or service design (FCA Handbook p.4). The new Agency appears to be making aggressive use of its powers (Binham 2015).

While this quickening drumbeat of regulatory innovation attests the pervasiveness of uncertainty in collaborative production, the difficulties in implementation reflect the contradictory incentives for both firms and administrative authorities facing the new circumstances. On the one hand, increasing uncertainty reduces information asymmetries, thus diminishing firms' strategic advantage over the regulator and increasing the returns to cooperative hazard identification. Firms, moreover, are linked not only by shared suppliers, but also by common interests in avoiding disasters that taint the reputation of all and in learning from others experiences before encountering problems in their own operations. Such circumstances also favor cooperative construction of risk identification and incident reporting systems (Gunningham et al, 2004).

But, on the other hand, faced with the practicalities of collaboration, large and capable companies may think it more prudent to build such systems internally, and extend them to key suppliers by contract, rather than collaborate with less able partners, or reveal proprietary techniques to competitors. Less capable firms may resist exposing vulnerabilities to outsiders, and prefer to protest new regulatory requirements they may not be able to meet. Trade associations, representing firms along the whole continuum of capacity, will be pressured by some members to help organize incident reporting, but pressured by others to oppose new obligations (Gamper-Rabindran and Finger 2013; Finger and Gamper-Rabindran 2012).

Similarly with regulators. Some regulators, and their political constituents, may see cooperation with industry in incident reporting and related systems as an effective way to hold private actors accountable for responding to rapidly changing conditions. Others will view such cooperation as an abdication of public authority to the private sector (Steinzor (2011).

But although interests diverge there appears to be directionality to developments. The rapidly increasing rigor of incident-reporting systems in industries, such as oil and gas, where they have a long but fitful history, the abrupt centrality of such systems in industries, such as food safety, where they until recently had a marginal role, and the introduction of this approach into industries, such as financial services, to which they once seemed alien—all this points to a tectonic shift in the nature of regulation, away from compliance as action in conformity with fixed rules and towards an obligation to collaborate in the identification and mitigation of emergent risk. Even half-measures in this direction, we will see, tend to be self-re-enforcing, as they reveal enough information to prompt further movement, though often only in the aftermath of yet other catastrophes. But even assuming such tectonic change is in progress, only the general line of thrust is discernible in advance; local outcomes depend on the particular context.

In this essay we look closely at developments in the Norwegian offshore oil and gas industry and its regulator, the Petroleum Safety Authority (PSA) to better understand the co-evolution of vertically disintegrated industry and new forms of

incident reporting based regulation. Norway is particularly revealing in this regard, as the industry was built initially on hierarchical foundations that make recent moves toward greater disintegration and collaboration by both industrial and regulatory actors especially salient.

Take first industry: Production on the Norwegian continental shelf (NCS) began in the 1970s and has been throughout dominated by the national champion, Statoil. Since the turn of the millennium, however, Norwegian suppliers have become increasingly innovative and independent. They have successfully globalized, while Statoil and other established operators continue to be burdened by internal rigidities and difficulties in supply-chain coordination. Moreover, these difficulties, even prior to the recent decline in oil prices, animated new operators and independent suppliers to form innovative consortia that achieve significant increases in drilling efficiency without jeopardizing safety. Persistently low oil prices makes the need to cut costs through efficiency gains all the more urgent, and further enlarges the space for organizational innovation.

Like Statoil, the PSA's trajectory is from early success to some disorientation in the face of new circumstance. Since the Alexander L. Kielland semi-submersible rig capsized in 1980, killing 123 persons, there have been no rig disasters on the NCS. Aggregate statistics show a long-term reduction in important risk factors such as the frequency of small hydrocarbon leaks. By the standards of popular and academic discussion the PSA is a model agency (Benneer 2015): It has neither been captured by outside interests, nor is it paralyzed by bureaucratic procedure: While the PSA monitors operators closely, and alerts them to possible unaddressed risks and lapses in managerial control, it strictly refrains from proposing or endorsing solutions, lest it create safe harbors that discourage innovation. Operators alone bear the ultimate responsibility for securing operational safety, preventing environmental harm, and searching continuously for the best available solutions to HSE problems. Public oversight is thus complemented by strict private liability rules.

The PSA's independence and rule making flexibility are buttressed by the participation of strong oil industry unions in a tripartite system of problem solving. Norwegian discussion attributes a large part of the PSA's success to this "Nordic" or "Norwegian" model. For these and related reasons the PSA is widely regarded as a world leader in offshore drilling regulation (Lindoe et al 2013).

But on closer inspection operations on the NCS are more catastrophe-prone than first appears. In May 2010, almost exactly a month after Deepwater Horizon exploded, as gas from the reservoir rose to the platform during well cementing, there was a similar gas influx at well C-06 in the Norwegian Gullfaks field. Had a favorable wind not dispersed the gas, the outcome would have been catastrophic.

The information management failures within the operating company and between it and its suppliers that caused this near miss were strikingly similar to those of another, also potentially disastrous incident at the Snorre A platform in November, 2004 (SNA 28.11.2004 –IRIS report, p 34). Far from learning from the Snorre A incident how to induce firms to address such safety-critical coordination problems, the PSA's well intentioned but fitful demands for improvement (unaccompanied by support for capacity building) apparently contributed to a succession of flawed reforms by the major firms that created further confusion and new risks. Put more generally, independence and flexibility are necessary but not sufficient conditions for regulatory success under current conditions.

Over the last decade, both the PSA and the industry have been responding to the near misses and the apparent failure of the Norwegian Model to learn (Engen, O. A. H., et al, 2013). The PSA has organized investigations into hydrocarbon leak causes, surveyed operating well integrity, and collected data on shortfalls in safety-critical maintenance. The NOG, focusing more and more directly on firms' need to learn from each other about emergent hazards has organized fora for analyzing the causes of leaks over the entire life cycle of a well,

The upshot is an incipient incident reporting system, albeit a voluntary and therefore incomplete one, in which participants respond or not to incident reports at their own discretion. In principle the PSA could make participation and response obligatory by redefining the extent of firms' existing obligation to maintain safety management systems. But doing so would require the agency to rethink its own role, extending the focus of monitoring from individual firms to the industry as a whole, and this shift would require a coordinate redefinition of the relation between the NOG and its members. Norwegian developments thus help us better understand how uncertainty prompts more rigorous collaboration among firms, and between the firms and the regulator, while highlighting the political and organizational difficulties that might obstruct such collaboration.

The remainder of this paper is in six parts. The next reviews the literature on regulation and on the hazards associated with complex, highly interdependent production, underscoring their mutual inattention to the information pooling and learning practices increasingly central to production and regulation. Part 3 surveys the development of the oil and gas industry on the NCS and the key features of the current regulatory regime. Part 4 details the regime's increasingly apparent costs while Part 5 looks to signs of renewal in the emergence of new consortia that outperform incumbents, and in the emergence, under the auspices of the NOG, of incident reporting fora that cover the entire life-cycle of a well from drilling to plugging. Part 6 concludes.

2. Regulatory Breakdown or Renewal? The Limits of Current Debate about Regulation

The literature on the relation between regulation and the avoidance of catastrophes arising from complex interdependence is, with a few, important exceptions, disjoint. The economics literature focused first on problems of capture, and then on market-based mechanisms for addressing problems in pricing in networks and other interconnected production systems. But that literature ignores the organizational hazards that interconnection creates. The debate in organizational sociology on complexity and catastrophe is dated: The pessimists see a tendency in modern technological development towards systems too complex to control; the optimists point to counterexamples of organizations that avoid catastrophe by inculcating a culture of vigilance. But neither side considers the kind of highly innovative, interconnected organization at issue today; nor do they address the role regulation does or might play in influencing outcomes. The result is a conceptual gap at the point of interest here: The intersection of the co-ordinate changes in industrial organization (disintegration/collaboration) and regulatory organization. This gap is only partially bridged by some thoughtful studies of regulatory innovation. We review these debates to highlight and clarify the assumptions of our approach in contrast with more familiar ones.

Economists in the US turned to the study of regulation in the 1960s and 70s, as the sector-specific, New Deal agencies passed their apogee. The agencies' public charge was to ensure orderly and fair competition in the interest of both firms and consumers. The Interstate Commerce Commission regulated railroads, then trucking; the Civil Aviation Board oversaw commercial aviation, the Federal Communications Commission broadcasting and telephony. In fact, as Stigler and others documented, regulated firms used political influence to ensure that legislation or the administrative agency responsible for applying it favored incumbents, most effectively by restricting entrance to the industry (Stigler 1975; 1988). The returns to such protection were enormous to its few beneficiaries, while the costs were almost imperceptible to the countless consumers to whom they were ultimately charged. Capture became synonymous with incumbency protection.

As these sector-specific agencies were dismantled or reoriented beginning in the 1980s-- in part a reaction against capture, in part an early recognition of the disintegration of industry that later gave rise to cooperative production-- the focus of regulation shifted to economy-wide problems: pollution, the use of hazardous materials, product safety and consumer protection in general. Capture became more difficult because it required cross-industry alliances, but also less rewarding because the new rules applied to all engaging in certain kinds of conduct, without distinguishing between insiders and outsiders. Instead of seeking preferential treatment, regulated entities' sought a general relaxation or evisceration of the rules: de-regulation (Posner 2013).

Economics too shifted focus in the 1980s and 90s, from treating regulation as a special topic in political economy—the sale and purchase of influence—to reconceptualizing it as an instance of a broader class of principal-agent problems: to incentivize agents to execute her plans, the principal must also induce agents to reveal private information about the costs of alternative actions—without which it is impossible to devise efficient incentives. In this perspective regulation was less concerned with institutionalized oversight and more with market mechanisms such as contracts and auctions for eliciting the information necessary for effective decision-making (Laffont 1994). Thus, when confronted with catastrophes such as the Macondo blowout or the financial crisis, economists are inclined to propose liability rules that in theory give private actors the incentives to seek the optimal level of precaution (Benneer 2012; Viscusi & Zeckhauser 2012). But as noted above Norway, for one example, already has liability rules of the intended kind, without achieving the expected results; and the monitoring regimes that it and other countries are constructing in response to the limitations of these liability rules are nearly invisible from the economists' principal agent perspective.

Nor does organizational sociology light the path of current developments. That discussion has been under the sway of debate between Perrow and other partisans of “normal accident” theory (NAT) and partisans of “high reliability” organizations (HRO) since the late 1980s. As the name suggests, normal accident theory takes catastrophes to be inevitable, not aberrant (Perrow 1984; Beck 1992). They result from the rapid and unforeseeable propagation of disruption through interacting subsystems typified by the reactor core meltdown at Three Mile Island. Efforts to mitigate the risks by introducing alarms, fail-safe mechanisms or back-up systems backfire because they introduce more complexity. And, in any case, the trend is towards larger-scale, more interdependent and hence more catastrophe-prone production. HRO theory responds by pointing to the extremely low accident rates in

air traffic control and aircraft carrier launches and recoveries (in peacetime) to demonstrate that sophisticated technologies can be operated safely (LaPorte & Consolini 1991; Roberts 1990). Safety, the argument continues, depends on operators (inculcated to be) preoccupied with the possibility of failure, attentive to “weak signals” of disruption and, when appropriate, willing to rely on experience in disregard of bureaucratic rules (Weick & Roberts 1993; Weick & Sutcliffe 2011).

In retrospect the two arguments talk past each other, and neither anticipates the current constellation of co-produced uncertainty and responses to it. HRO does not join issue with NAT because the sophisticated technological systems it considers are not highly interdependent or tightly coupled as in nuclear power generation. Air space is divided into loosely coupled sectors and aircraft are carefully separated at takeoff, in flight and on landing in both civilian and carrier operations. Thus deviations in a sector or flight can be accommodated without causing a cascade of disruption in adjacent operations (Leveson et al 2009). Moreover, neither the nuclear power plants at the heart of NAT nor the air traffic control systems that inform HRO are subject to the constant, joint innovation that creates uncertainty in the economy today. There are very few reactor types in service in the US, and almost all were built before 1974; the technology of launching and recovering carrier aircraft is likewise extremely stable, and operating personnel have “nearly full knowledge” (LaPorte & Consolini 1990 p 19-48 (esp 29-30; Leveson et al p 238) of it.

Of course it is possible that NAT is right about the inevitability of catastrophe, and innovation just makes a dire situation worse. And if NAT is not right, it is possible that HRO’s argument about a culture of vigilance or safety explains successful operations. But the evidence weighs against both possibilities.

Although NAT predicts that both complexity and risk will grow with time, if only through misguided efforts to reduce risk, nuclear power generation—the prototypical instance for the theory—has proved remarkably safe. (Russian nuclear power operations are “vastly” safer than at the time of the Chernobyl reactor meltdown, in largely because of collaboration between Russian operators and their foreign counterparts, under the auspices of the World Nuclear Operators Association (World Nuclear Association The Chernobyl Accident of 1986); the reactor meltdowns at Fukushima resulted from failure to design against an exogenous event—a tsunami—not the inherent complexity of the installation (World Nuclear Association, Fukushima Accident). Moreover, as Norwegian experience shows, there are dramatic and persistent differences in management’s capacity to control precursors to catastrophe. In sum, complex technological systems can be operated safely, provided that their operation is organized to be safe

We will see furthermore that there is much circumstantial evidence for the view that safe operations are not a matter of a stand-alone culture. Rather, there is an interplay between the creation of institutions for detecting and correcting the underlying causes of abnormal events—routines for interrupting and eventually modifying routines—and the attitude and disposition development needed for a safety culture: Incident reporting systems and the investigations they trigger foster vigilance, and vigilance underwrites reporting regime practices, thereby inducing the continuous scrutiny and revision of organizational regimes characteristic of experimentalist or recursive institutions (Kringen 2008).

A more recent approach, meta regulation, is rooted in the study of regulation itself,

rather than in the disciplinary concerns of economics and sociology (Gilad 2010; Gunningham 2010; Coglianese & Mendelsohn 2010). It anticipates key aspects of the recursive model under discussion here, especially the changed regulator role. Rather than presuming to write uniform rules based on scientific study and such information as industry can be incentivized to provide, the meta regulator induces heterogeneous, ground-level actors to actively investigate the particular risks they face and determine how best to mitigate them. Forms of meta regulation differ in the way they conceive the heterogeneity of the regulated actors, the weight they give uncertainty, and, correspondingly, in the allotted regulator supervisory responsibilities.

For management-based regulation, for example, simple technical and managerial idiosyncrasies render firms in many industries heterogeneous. If it is also impractical to observe regulated conduct directly and sanction non-compliance, regulators cannot write rules that apply effectively to all. Moreover, in such settings production idiosyncrasies often cause management itself to overlook cost-efficient possibilities for reducing harms. Given this double cognitive default by the regulator and the regulated entity, the management-based approach recommends a duty to plan harm reduction. The core idea, exemplified in the Massachusetts Toxics Use Reduction Act (TURA) of 1989, is that planning and execution are complements: Obligated to prepare plans for reducing the use and production of toxics, firms will discover opportunities for affordable, perhaps profit maximizing improvement that the regulator could not have anticipated but management will have overlooked; the discoveries make the plans self executing even without a formal requirement to act on them (Coglianese & Lazer 2003; Bennear 2012).

But absent an obligation to enact plans and report results, recursive regulatory system improvement occurs only if the planning exercise touches off a self-sustaining planning and correction cycle in individual firms. This is not the case. In a careful environmental performance study in Massachusetts and the 13 other states that adopted similar regulation, Bennear found that pollution prevention planning reduced toxic releases by 30 percent—but only for the six years following statute adoption (Bennear 2007). The planning obligation does reveal unexpected opportunities for improvement but does not lead to recursion that makes improvement continuous.

The responsive regulation model proposed by Ayres and Braithwaite, in contrast, sees heterogeneity in the actor's disposition to comply or not with regulatory obligations. The focus accordingly is on the optimal allocation of regulatory attention to good and bad types. In the model the rational regulator plays tit for tat with firms: cooperative firms that make good faith and successful efforts at risk reduction get little attention, while uncooperative ones get a lot. The cost of this optimization is that regulators and other firms cannot learn from the most successful cooperators' good practices (Ayres & Braithwaite 1992; Baldwin & Black 2008; Black & Baldwin 2011).

The recursive or experimentalist model differs from these in emphasizing the importance of uncertainty, and with it the need for collaborative investigation by firms of emergent joint risks and potential responses to them. A crucial task for the meta regulator is therefore to help organize this investigation and continuous improvement both in the capacity to detect risks and to ensure that firms respond to warnings. Given the rich and continuous information flows about firm conduct and capacity such regimes produce, a meta regulator responding effectively to uncertainty will also be well equipped to address heterogeneous firm-type and

technical set-up problems, while the reverse is manifestly not the case.

But nothing is served by making too much of these differences: Think of the recursive model emerging in the Norwegian offshore oil and gas industry as a member of the meta regulation family in which the meta regulator, faced with uncertainty, has responsibility for supervising and if need be helping to organize both pooled risk reduction plan evaluation and an incident reporting system to avert immanent harms and update risk awareness and understanding.

3. The Emergence of the Current Norwegian System

3.a Norway as Developmental State: From Infant Industry/Condeep to NORSOK

When North Sea Shelf oil was discovered in the 1960s and 70s, the Norwegian state actively sought to develop a Norwegian industry. At the time, a few giant multinational companies dominated the global oil industry and virtually no oil exploration or production know-how existed in Norway itself. To get it, the state pursued a two-pronged strategy (Engen 2009).

First, it allocated concessions to foreign MNCs to maximize its own returns (through leases and taxation) and required producers to use Norwegian suppliers and materials for drilling platform construction and product transport to and from the wells. Second, the state created Statoil, gave it extremely valuable concessions, and enticed international technology suppliers into deals that transferred know how and technology both to Statoil and to the key private suppliers Aker and Kveerner.

The strategy yielded a distinctively Norwegian platform technology -- Concrete Deep Water Structures or Condeeps -- which were heavy, gravity stabilized drilling structures capable of withstanding the North Sea's great depths and turbulent seas. Their construction redeployed and further developed longstanding Norwegian know-how with concrete (developed in the hydroelectricity generation business), and marine engineering and shipbuilding.

By the mid 1980s, the Norwegian oil industry was profitable and Statoil and key Norwegian suppliers had become internationally competitive technology producers (Engen 2009; Andersen 1998). When the new Gullfaks field was opened early in the decade, for the first time virtually all of the operators (Statoil, Norsk Hydro, Saga) were Norwegian, as were all of the crucial suppliers. Within a little more than 20 years, the infant industry strategy had succeeded in creating a Norwegian oil industry.

Success was short-lived, however, as falling oil prices in the 1980s revealed high Norwegian costs (especially labor costs) and forced structural adjustment. The state moved decisively to abandon the infant-industry strategy's top down tactics by privatizing Statoil in 1991, and then, in 1993, creating the Norsk Søkkel Konkurransesepisjon (NORSOK), a framework program for re-structuring the industry that gave the oil companies and the main suppliers greater freedom to design contracts, pursue new technologies, and choose sub-suppliers and drilling locations. Operators and suppliers were encouraged to act more cooperatively to

lower costs and develop competitive technologies and standards. The overall goal was to reduce the cost level on the NCS by 50 percent (Engen 2009 passim; Engen 2013 esp p. 347).

All of these efforts produced ambiguous results. On the one hand, the industry abandoned the Condeep structures and moved into the production of more technologically sophisticated floating drilling platforms, production vessels and sophisticated automated subsea technologies. But on the other hand the new flexibility generated significant price competition in the industry, leading to concentration and mergers among Norwegian suppliers and operators: Aker and Kvearner merged in 2001, while NorskHydro first acquired the much smaller Saga in 1999. Then the privatized Statoil acquired the oil and gas assets of NorskHydro in 2006. These reorganizations allowed adjustment to the cost environment, but left in place elements of hierarchy within and among firms that impeded subsequent innovation (Stinchcombe & Heimer 1985 p 32).

3.b The Norwegian Regulatory System: PSA, Tripartism and NOG

The Norwegian off-shore regulatory system consists of three disparate and imperfectly integrated complexes. The first, centered on the PSA, is a functional regulation system involving strict operator liability (called “internal control”) and indirect safety system monitoring (known as “acknowledgement of compliance”). The second, centered on union – management relations, sets an agenda for addressing risks to personal safety through negotiation (at the national level), and solving safety-related issues informally, by drawing on professional and craft capacities (at the workplace). The third, inchoate, complex is centered on the NOG and emerged in part in response to the PSA’s efforts to study industry-wide risks. It is laying the ground for an incident-reporting regime for the industry. Imperfect integration between the systems produces tension and conflict that broadly increases the vulnerability of all actorsly integrated at best, in tension or at odds at worst, potentiallycurrent restructuring demands under harsh conditions.

In the early, 1970s, command-and-control regime, the regulator prescribed the design specifications for permissible equipment or installations. In the functional regime that has developed since then, and is codified in regulations from 2010, the regulator specifies only the general requirements that equipment must meet if it is to function safely in the intended use conditions. Typically the regulator and private consultants provide greater elaboration and detail through guidelines or “national books”. Often the incorporation of domestic and international standards secret even more detail into the guidelines.

The internal control doctrine, which establishes the operator’s ultimate liability for damages caused, complements functional regulation. This means that even if a regulated entity complies with guideline specifications and standards, it must still, in theory, actively search for better alternatives to the indicated solutions; and if it chooses an alternative, it must justify its choice to the authorities (Kassen 2013).

In addition, several statutes regarding workplace safety have been read together with the internal control doctrine to obligate regulated entities to institute safety

management systems (WEA, Section 2 a). Such systems establish company-specific safety norms, and routines for ensuring that these norms are enacted. Increasingly the PSA checks compliance by examining safety management system scope and reliability rather than by direct inspection. “Compliant” safety management systems, however, do not lessen operator liability for damages. The regulations insist that operators have an overriding, continuing duty to “see to it that everyone who carries out work on its behalf, whether directly or through employees, contractors or subcontractors, complies with requirements stipulated in the health, safety and environment legislation.” (Bang & Thuestad 201, p.214)

In the same spirit, the PSA issues no official approval to operate or operating permit. Instead, it issues an “acknowledgment of compliance” (AOC), which underscores both the provisional character of the permission to operate and the Agency’s refusal to endorse any solution officially.

Entwined with this internal control and safety management complex is a second, tri-partite regime of labor-management cooperation, established under state auspices. The Working Environment Act of 1977 gave employees the right to halt work upon detecting an immediate threat to health and well being without incurring liability for the costs of the stoppage (Bang & Thuestad 2013, pp 210f). This led to extensive collaboration between safety managers and worker safety representatives to address pressing issues at the workplace level (Kringen 2008 pp 61-71;80-97).

National level collaboration came in the following decades, and is now organized in two tri-partite fora: The Safety Forum, set up in 2000, discusses matters bearing on health and safety, but not collective bargaining, with the regulator. The PSA regards it as a setting to develop the management and labor trust and mutual understanding that is the informal foundation for formal regulatory compliance (Bang & Thuestad 2013 p 223; Kringen 83-4). A year later, NOG formed Working Together for Safety (SfS), which reaches beyond unions and employers associations to include oil firm, drilling contractor and supplier representatives. SfS operates through working groups, which identify the root causes of problems in particular areas (eg falling objects) and harmonize and attempt to diffuse best-practice responses (Bang & Thuestad 2013 p 223; Kringen 83-9).

The third complex, in which NOG plays an increasingly active part, arose in connection with the preparation and use of *Trends in risk level in the petroleum activity* (RNNP). The PSA has published this annual report since 2001. RNNP uses the incidence of defined hazard and accident conditions (DFUs), such as low-level hydrocarbon leaks, to track changes in personal injury levels and catastrophic failure risks in the industry as a whole. New indicators are introduced from time to time. In 2006, for instance, the PSA conducted a well integrity pilot survey among seven operators on the NCS, and found that 18% of the double barriers between production wells and their surrounding formation were impaired (PSA 2006). As a result the RNNP now includes a well integrity traffic light rating —green for two functioning barriers, red if both are impaired, with yellow and orange situations in between (Kostøl 2014). Such data alerts the PSA, industry and the public to alarming developments and may trigger further inquiry (Lauridsen 2012). Collaboration in the RNNP prompted the NOG to undertake research projects of its own, and these have helped create shared understandings of investigation and information pooling which, as we will see in Part 6, underpin the emergence of an incident reporting system.

4. The limits of the current regime

The regulatory constellation organized in the PSA and the tripartite fora has, like the Condeep and NORSOK development regimes, served Norway well. But hidden costs and limits are emerging and increasingly becoming barriers to further risk reduction and increased efficiency. In this part we look first at these hidden costs in regulation, then in industry organization.

4.a Limits of self-limitation as a regulatory strategy

Regulation under uncertainty depends on collective learning, especially by firms: Only rapid learning from pooled experience makes it possible to recognize operational risks that can't be identified ex ante before they are manifest as disasters. But the PSA, as we have indicated, does not focus on building a collaborative incident reporting system infrastructure for on-going information exchange among firms about hazards and their mitigation. Rather the agency engages with the principal operators bilaterally. Moreover, the PSA primarily emphasizes ex ante risk reduction through elaborate modeling exercises and does little to direct attention to the operational risks that emerge only after a project receives an AOC. Attention to ex post risk is further narrowed by the traditional misconception that reduction of personal injury risk lowers catastrophe risk. Finally, tri-partite fora distract from ex post risk by constantly foregrounding agenda issues with which trade union central headquarters are particularly comfortable.

The focus on individual operators. The PSA monitors major operator performance with dedicated multi-functional teams that suggest, with increasing threat of penalties if need be, areas for (urgent) organizational improvements. The teams regularly review the operation and data produced by "their" firm's safety management system and conduct periodic on-site audits. Systematic problems attract sustained interest. For example, the corrective to preventive maintenance ratio in a firm or facility is a serviceable indicator of the organization's ability to keep operations under control: the higher the ratio, the more often intervention corrects a breakdown that thorough understanding of situation could have prevented. A firm with a troublingly high ratio will be asked to develop and implement a plan to redress the balance.

Increasingly, these dialogues prove ineffective for two closely related reasons. First, the focus on operators largely ignores the extensive contemporary collaboration between drilling contractors and specialized service providers. More and more the operator only exercises a supervisory function on both offshore platforms and on shore activities. Thus close monitoring of operators can easily ignore the most important part of operations. Second, precisely because the operators depend on collaborations that they do not completely control, their ability to correct systematic problems within the PSA's typically tight time constraints is limited. Hence problems are identified but not resolved, and systemic vulnerabilities accumulate. The RNNP for 2013 reports that the total preventive maintenance backlog for all NCS production facilities was a little under 10,000, slightly below the year before, but substantially above the level (just above 6,000 hours) for the preceding two years. The corrective maintenance backlog in 2012 and 2013 was twice as high as in the two preceding years. There is, moreover, "great" and persistent variation in the maintenance performance among operators" (PSA 2013, pp 30-34)

The limits of Quantitative Risk Analysis (QRA). The PSA emphasizes the use of QRA to reduce foreseeable risks. QRA is based on historical failure rate data: a particular part or component is known to fail with a certain frequency under certain conditions. The more such parts are used in an assembly or installation, the more likely the ensemble will fail. QRA thus simply extrapolates from the specific known part failure rates to estimate the failure likelihood of a structure that combines various part quantities in novel ways.

This analysis is subject to two important limits. First, there is the domain problem: Failure rates are derived from experience under a range of conditions; if parts or equipment are used in settings outside the range, the historical evidence may be unreliable. Take a crude but effective illustration of the problem: There are 50,000 wells off-shore in the Gulf of Mexico, but only 41 high temperature/high pressure wells of the Macondo type. Is the failure or blowout rate of high temperature/high pressure wells in the Gulf of Mexico closer to 1/50,000 or 1/41? How could we decide without recovering information about, for example, the nature of the formations drilled, that has not been included in the failure rate data bases?

A second limit on this kind of risk analysis concerns the exclusion of “human factors,” or, more generally, organizational breakdowns as a disruption source. QRAs assume that parts as designed and built have an inherent failure rate. But many dangerous outcomes—hydrocarbon leaks during valve maintenance, for example—are caused by (organizationally induced) human misuse of equipment. Making the equipment more robust will not by itself mitigate the hazard risk. We will see below that realization of the relative importance of organizational as compared to technical sources of breakdown is central to the push within industry and the NOG to construct incident reporting systems which do make “human factors” conspicuous (Skogdalen and Vinnem 2012).

By insisting that firms applying for AOCs “demonstrate” that their projects do not exceed precisely defined risk levels, the PSA invites gaming of QRA models. It inadvertently gives undue weight to the historical knowledge used in ex ante, planning-stage risk mitigation, as against learning in the ex poste, operating phase. Organizational factors are thereby, subtly and unintentionally downplayed in catastrophe avoidance.

The confusion of increased personal safety with catastrophic risk reduction. The WEA was remarkably far-sighted, obligating employers not only to establish management systems for protecting (and continuously improving) workplace safety, but also obligating firms to afford employees opportunities to participate in organizing work and otherwise exercising their autonomy. Of the Act’s manifold purposes, concern for safety has been most robustly institutionalized and absorbed in union and management cultures. Safety concern shades into the conviction that successful individual risk management induces or facilitates broader management changes—especially more rapid learning from error—that generally reduce risks of dangerous failures. Such convictions have subtly shaped the PSA’s regulatory priorities and focus.

But experience in the last two decades has consistently shown that heightened personal safety does not make operations catastrophe-proof. Practitioners and academics repeatedly stress that the two domains are only loosely connected, and

that it is dangerous, therefore, to use personal safety (change) measures as proxies for trends in what is variously called process safety or asset or technical integrity. For example, the US Chemical Safety and Hazard Investigation Board's careful review of the causes of BP's Texas City refinery fire in 2005, which resulted in 15 deaths, finds that "a very low personal injury rate at Texas City gave BP a misleading indicator of process safety performance."(CSB p 19) The Baker Report on the same incident is equally emphatic in criticizing BP's use of use of injury rates to measure process safety (Baker p xiv; cf Hopkins 2000 esp p. 460).

The PSA is aware of all this. The webpage introducing the 2013 RNNP says flatly that the RNNP process has led to "a recognition that traditional indicators, such as personal injury statistics, are of limited use in measuring major accident risk." But revising the Agency's priorities accordingly is difficult. Safety management, where safety is still mainly understood first as personal safety, is a well-established profession in Norway, especially in the off-shore industry; the PSA is entwined with it through daily exchanges and personnel career paths that circulate from industry to regulator and back. Beyond these ties, the agency is perhaps subliminally inclined to associate personal and process safety because the link is highly valued by unions and thereby given prominence in tripartite institutions.

The rigidity of the tri-partite model. As we saw, tri-partite safety issue discussion is institutionalized in two fora—the Safety Forum, convened by the PSA, and Sfs, convened by NOG. The limits of such bodies stem from the difficulties that trade unions in all the advanced countries have had in connecting effective shop-floor and enterprise-level labor-management cooperative problem solving to regional and national level coordination and leadership. Peak level difficulties in adjusting to continuous organizational and technical change are deeply rooted, the failure to connect local problem solving with the national agenda is recurrent, and the reasons for the missed connections are ill understood. For present purposes we note only that failure to solve this problem leaves the Norwegian unions, like their counterparts elsewhere, inclined to advocate familiar issues, in this case workplace safety. In the Norwegian oil industry this is manifest in a long-running and occasionally acrimonious dispute about the particulars of safe and affordable life boat design for evacuating crews on endangered platforms, or, about fire hose location and design. These disputes take on symbolic significance and raise familiar, politically charged questions—Profits before people? These are fundamentally important matters and are rightfully central to tri-partite discussions (Kringen 2008 pp 94ff; 267- 284). But however they are resolved, their very centrality crucially influences broader regulatory agenda setting. They can thus reinforce the misleading impression that making personal safety the highest priority is the best way to make personnel safe.

If the analysis so far is correct, it is only a slight exaggeration to call these limits to the PSA regime unforced errors: Nothing in legislation, or the Agency's founding commitments, would have prevented, or would today prevent, an interpretation of the internal control doctrine focused on support for an incident reporting infrastructure, rather than close monitoring of key operators, or de-emphasis of QRA in favor of more careful firm-level safety management and incident reporting system review. We return to the possibilities for re-orientation below.

5. Pressure on Statoil

While NORSOK successfully responded to the infant industry's problems, the regime created relatively closed and hierarchically ordered organization forms that now struggle to accommodate the flexibility within and among collaborating firms required for successful adjustment today.

The most authoritative documentation of blockages in the Norwegian industry's organization is by Petoro, a state-owned company that manages Norway's portfolio of petroleum and natural gas exploration and production licenses. Petoro's most recent findings reveal that the Norwegian industry, and especially Statoil, is not only falling behind foreign competitors, but is actually backsliding—failing to meet benchmarks set by its own past performance.

One measure of this decline is that 25 representative, routine drilling operations take on average twice as long to carry out today as they did *in the same wells* roughly 20 years ago. Figure 1 displays the comparison.

[Figure 1]

In large measure because of this operational slowdown the number of wells drilled per rig, per year has declined dramatically, so drilling costs increase while recovering dwindling reserves becomes more drilling intensive. The same real productivity declines are captured in increases in engineering hours per well or per ton, and workers needed to extract a barrel of oil (cf: Osmundsen and Tveterås 2010).

Second, even as the industry is doing familiar things more slowly, new technology diffusion in the field is slowing. Norway fell from 10th in 2005 to 40th in 2013 in the international league table of oil-industry technology adopters.

[Figure 2]

This nosedive is especially puzzling because, as the header in Figure 2 notes, NCS firms are “quick to try new technology.” It would be surprising if they were not, as Norwegian capital goods suppliers to the industry became leading global players in these years. Local customers must have encouraged, at least initially, new equipment development, and given useful performance feedback. What then accounts for NCS firms (especially Statoil's) broad reluctance to push initial, isolated enthusiasm for innovations into general deployment? What is the relation, if any, between the diffusion slowdown and the slowdown in the execution of familiar routines?

The Petoro presentation speaks only of “creeping inefficiency” caused by self-defeating perfectionism and inability to prioritize, leading to excessive complexity in operations. The report also refers to friction in customer-supplier relations, and hence “the need for operator-supplier cooperation models” that give suppliers “the opportunity to participate” in deploying new technologies..

A more specific conjecture—compatible with Petoro’s explanations—connects the slowdown in routine task performance with the delay in new technology diffusion. Many new technologies make possible more continuous and precise drilling operation measurement and control. But the level of cooperation between those observing the data flow and those conducting the drilling operation determines whether the technology in use increases efficiency or actually decreases it. Consider instrumentation for measuring drilling tool vibration. When coordination between data monitors and tool operators is high, early signs of vibration increases touch off a rapid search for ways to avoid reaching levels that jeopardize the tool.

When cooperation between data monitors and tool operators is low, the operators respond cautiously, protecting the tool by slowing drilling, perhaps below speeds that would have been acceptable in an earlier period, before vibrations were measured. In this case fear of mistakes and the search for “perfect solutions” lead to the proliferation of prudent, but inefficient, rules of thumb. As the sources of potentially alarming information increase, so too do the number of rules, and with them the number of trip wires that slow production. As managers come to see this connection, investments in new technology decline and the slowdown in routine operations fuels a disinclination to adopt innovations broadly.

But regardless of the precise explanation, it is clear from the Petoro account, and concurrence from many industry actors, that high costs stem from coordination problems, and that the latter are exacerbated by two additional and widely remarked circumstances: the increasing shift of platform control to on shore units that lack the necessary contextual information to make good judgments; and decreasing head drill manager tenure on the rigs. What was once the apex of a career is now a stepping-stone to an off-shore management position.

All of these pathologies and many related ones besides are noted in a widely read report by the IRIS institute in Stavanger on the Gullfaks C near miss. The report, sponsored by PSA and based on extensive access to all players involved in the incident, underscores the organizational blockages pervasive in Statoil and calls attention to perverse interactions between the regulator and the firm, especially the failure of both the PSA and Statoil managers to establish routines that actually address the organizational problems that both identify as pressing.

6. Signs of Renewal

But the PSA, the NOG and the rig operators and supplier firms on the NCS are hardly supine in the face of these developments. Regulatory initiatives and the emergence of innovative production consortia hint at the possibility of robust systematic learning in the service of both safety and efficiency on the NCS.

On the regulation side, two important incident-reporting programs have emerged: The Hydrocarbon Leaks Project and the Drilling Managers Forum and its Well Life Cycle Incident Reporting System. The history of both goes back to the turn of the millennium, but in both cases developments have accelerated and become more institutionally salient.

The Hydrocarbon Leaks Project. Hydrocarbon leaks are a major precursor of accidents in the off-shore oil and gas industry. In 1996 the NCS Industry started registering leaks greater than .1kg/second—the flow rate above which dangerous accumulations easily arise. The frequency of leaks was then increasing. It peaked

in 2000, as the RNNP began publishing the indicator annually.

The alarming trend led to two parallel projects between 2003 to 2008. NOG used accident reports the GaLeRe (gas leak reduction) project to establish a rough classification of leak causes and suggest preventive measures (Røed et al 2012). In the second project the PSA traced the origins of many leaks to actions by improperly trained personal and introduced courses on manual operations with flanges, fittings, valves and other equipment in response (Vinnem and Røed 2014 p. 88).

Although the frequency of leaks fell during the GaLeRe and PSA projects, it rose in the following years. In 2011, NOG, in cooperation with major NCS operators, organized a two-year, follow-on project to look more deeply into the root causes of leaks (Røed et al 2012). The aim was to develop still more effective countermeasures by explicitly encouraging experience exchanges among NCS firms and between them and firms on the British continental shelf.

This study looked at the 33 leaks on the NCS from 2008 to 2012 for which company investigative reports were thorough and complete (Vinnem and Røed 2014 p 95). The results confirmed earlier findings that equipment failure is a secondary cause of accidents (accounting for 20 percent of leaks) while the primary cause are manual interventions (accounting for 60 percent). The novelty of the report was to establish that failures due to manual interventions are usually caused by upstream errors in *preparing* the intervention: for example, a routine instruction that ignored lessons from earlier experience, or reference to a manufacture's out-of-date drawing that did not correspond to the installed equipment. Fifty-nine percent of the faulty manual interventions resulted from such upstream failures while only 27 percent were caused by errors introduced during work on the targeted equipment (Vinnem and Røed 2014 p.98, Røed et al. 2012 p.10). The study thus pointed to the need for continuous monitoring of (deviant) organization routines—an implication re-enforced by the finding that the divergence between the best and worst companies with respect to leaks has increased in recent years (Vinnem and Røed 2014, Røed et al. 2012; Bennear 2015; Skogdalen and Vinnem 2012).

The project touched off a cascade of promising institutional reactions. Several companies have compared their best maintenance practices and the NOG has, together with a working group including representatives from all active major NCS firms, codified the project's results into a common best-practice guideline. The PSA refers to the project's material, giving it official weight. The project developed and introduced a standard questionnaire to address accident report inconsistencies and incompleteness, which draws attention to error incidence in various work process phases (Vinnem and Røed 2014).

Taken together the hydrocarbon leak project initiatives set the stage for improved reporting and more precise categories of analysis. And by making visible variation in individual firm performance, the project places even more pressure on laggard firms to adopt the project's version of industry best practices.

Drilling Managers Forum and Well Life-Cycle Incident Reporting. Roughly with the start of the new millennium, as the hydrocarbon leaks projects got underway, NOG began to develop, stepwise, and at least initially without any overarching design, industry-wide fora for the discussion, analysis and response to well control incidents such as sudden formation fluid influx into the wellbore—a “kick.” Eventually

specialized groups were formed to track and deepen understanding of problems emerging in each well life-cycle stage, from drilling to operation (well integrity) to plugging and abandoning. The groups are not yet a fully integrated system with common protocols for acquiring, analyzing and disseminating information; but they are surely more than ad hoc initiatives, and they are depicted in NOG's own presentations as the foundation of a comprehensive structure.

The first and still central component of this emerging structure is the Drilling Managers Forum (DMF), established in 2002 under the leadership of Jan Krokeide, a respected drilling industry veteran, consultant and NOG part-time employee. Drilling managers for 13 operating companies participated at the start (Boresjefer engasjert i sikkerhetsarbeid 2002). The new forum emphasized that safety risks were best addressed by developing shared understanding of problems and responses. In addition to promoting improved HSE, the Forum keeps abreast of operational and technological developments; fosters experience exchange and learning; comments on proposed regulations; and assists in organizing and staffing further projects (Krohn 2011).

The Well Incident Task Force (WITF) and the Well Integrity Forum (WIF)—the other two pillars of the emergent well life-cycle incident reporting system. The WITF convenes NCS operator and drilling contract managers to recommend ways to reduce well control event frequency and potential severity. The group analyzes recent well control incidents at monthly meetings and then posts elaborated versions of the cases (10 so far) on the web under the rubric of "sharing to be better." The detailed cases typically include logs showing instrumentation readouts from critical moments during the incident, and are pedagogically structured with questions like "would you have reached this conclusion?" The incidents invariably highlight organizational factors—the data operator on a platform asks a geologist on shore to provide a calculation parameter; the geologist, distracted, tells the operator to consult a value table; the operator chooses the wrong value; and so on. The constant refrain is the need to question taken-for-granted routines, or, as one participant put it in a meeting we attended, "Assumptions are the mother of all screw ups."

The second key group in the DMF constellation is the WIF. After the 2006 PSA study showing that nearly 20 percent of production wells were impaired, the WIF was formed to focus on the operating stage, after the drilling unit hands the well to the production managers. WIF produces guidelines on training, handover documentation and standardized barrier drawings and comments on regulatory proposals (Krohn 2011).

Figure 3 shows NOGs view of the system that has developed out of the DMF, including a reference to a third forum on plugging and abandonment, at the end of the well's life cycle. In recent revised standards hearing announcements, for example, the PSA refers to the same constellation.

[Figure 3] (Berg 2013)

These promising developments are hampered by the fact that firms' engagement at every stage is voluntary. Although it has substantial convening capacity, NOG's power depends on the trust of its members. It cannot compel actions beyond those they authorize or willingly tolerate. While this tension is inherent in the nature of trade associations, in the Norwegian context it is expressed in two distinct ways.

The first concerns the extent of participation in incident reporting. Although individual managers are often quite open to professional exchanges and joint problem solving, the companies they work for often worry that incident information may damage their reputation, or reveal management system detail they consider proprietary. So not all companies allow their managers to participate in the fora, and those that do may not clarify until the last possible moment just how much information they are willing to make public through an incident discussion posting to Sharing to be Better.

The second regards the protocols for collecting, analyzing and diffusing incident information and results. Companies are not formally obligated to employ the new hydrocarbon leak questionnaire, nor to pursue the root cause investigation the questionnaire prompts; nor to respond in any way to incident reports. The "sharing to be better" cases invite such self-reflection, but stop there. Firms are left to their own devices to absorb or not the lessons learned.

These weaknesses in the emerging NOG constellation are cast in stark relief when contrasted with the systematic linkages in the analysis and information flows within the most sophisticated company-based incident reporting systems, such as Shell Oil's Learning from Incidents (LFI) process. LFI both presupposes relevant stakeholder participation and has a bias toward organizational over simple manual or technological explanations of failure. Moreover, it complements its classification system for incident severity with a process for challenging classifications—an effective way of addressing the paradox that the eventual degree of severity may often be gauged only after an investigation triggered by a provisional estimate. "Causal investigation" aims to identify the organizational levels that ultimately "cause" the problem. For example, if a suspension wire on a crane breaks, the root cause might be located in a design problem, and the response might be to specify thicker wire for the intended purpose in the future. But the defect results also and more fundamentally from a failure in the organization of the design process, which overlooked the original misspecification. Finally, LFI analysis does not diffuse its findings through traditional reports. Rather it uses a document presenting the circumstances contributing to an incident to prompt discussion among relevant parties: Groups in facilities that could be implicated in similar incidents reflect, at each stage of the episode, on how *they* might have contributed to related problems—and what to do to avoid such contributions: The "observations inside conclusions" (OICs) (interview) produced by these groups often improve on solutions devised by the original incident investigation team.

The differences between current NOG/DMF system and company best practice are important, but should not be exaggerated. The latest revision of the Sfs guidelines for the "Best Practice for Examination and Investigation of HSE incidents" contains a thorough discussion of most cogent aspects of systems such as LFI, including a section on "alternative" learning forms that dovetails with the OIC's innovative and participatory features (Samarbeid for Sikkerhet 2014). This and much other anecdotal evidence suggest that the emergent NOG system is firmly connected to, and is not a backward variant of, the best company systems. The question, in other

words, is not what the participants in the NOG fora know, but whether or not hurdles obstructing implementation can be overcome.

New forms of firm organization and contracting

One sign of organizational ferment and renewal in the NC, is the creation of some 60 new firms, in different industry segments, by managers from established companies, especially Statoil. Although their impact is hard to assess, key managers are plainly responding to incumbent producer rigidities. Their willingness to take substantial personal risks to realize plans that could not be put into action within the existing structures recalls the behavior of managers of US Steel and other American integrated producers in 1970s and 80s, when they left to their firms to establish what is today the highly competitive minimill segment in the steel industry (Herrigel 2010, pp 100-138).

But the most conspicuous examples of contemporary NCS collaboration are new forms of drilling consortia that increase efficiency—to well above the area average—while reducing risk through rapid, joint learning. Traditional NCS consortia were makeshifts formed by smaller operators, none big enough to hire a rig alone. Typically the largest of the cooperating firms hired a rig contractor and service providers under terms that were then accepted by the others. This arrangement allowed smaller firms to access rigs, but largely precluded efforts to learn from on-going operations as the terms of cooperation were fixed once and for all at the outset.

Starting in the late 2000s, as rig contract prices climbed and efficiency concerns became paramount, smaller operators sought more control over drilling conditions.

The result was the creation of collaborative consortia: the operators jointly establish framework conditions with the rig contractor, a well drilling company (in effect the general contractor for the whole project) and a service supplier. The aim is to make collaboration systematic, linking all relevant players in ways that allow for rapid plan revision in light of problems encountered in their execution, and the capture and subsequent application of lessons learned in each step of the drilling campaign.

The West Alpha Consortium (WAC), formed in 2009 by five operators to drill 17 wells all over the NCS in 3 years, was one of the pioneers of these new arrangements. The lead operator was the BG Group, a British multinational. Consortium operators and the rig contractor, Seadrill, established general “safe efficiency” conditions in workshops and regular meetings before the rig began the drilling campaign. The consortium operators’ steering committee hired a single, integrated service supplier, and established a core offshore team (consisting of a day and night drilling supervisor, a logistics engineer and a safety coach) to assure key personnel continuity through the whole campaign and to allow rig counterparts to focus on urgent operational issues. Several new positions were created to ensure close and continuing planning and operational unit coordination at every well drilling phase: An “on-shore toolpusher” was posted from the rig to the on-shore planning group, so that the current operator was abreast of rig conditions and drilling programs could be optimized in view of a full understanding of rig capacities. On the platform, a rig contractor “optimizer” was embedded in the operator’s rig team to improve operational planning and execution by planning each well bore section. A “master action register,” continuously updated, captured lessons learned and passed them on to successive operators. WAC set a record for the fastest exploration well in Norway and operated for more than a thousand days without a

lost time incident (Thistle 2013). Petoro presents the WAC as “a benchmark for efficient drilling”(Petoro ONS Magazine 2014). A second consortium, including the BG Group and Det norske Oljeselskap (DNO), one of the NCS’s most innovative firms, achieved comparable results (Ribesen et al 2011a +b).

Whether the innovative elements of an incident reporting system in Norway together with changes in firm organization coalesce into a new regime that is both more efficient and less catastrophe prone than the present one is an entirely open question. The PSA could, if it chose, revise its understanding of the internal control doctrine to allow active encouragement of working groups while NOG revises its role as a trade organization to allow more active participation in the regulation informed by incident reporting. Encouraged by this rapprochement firms might relax the remaining restrictions on the pooling of “proprietary” information on incidents. The continued success of the new consortia and the lead firms in them could then prompt a revision of the contract regime to encourage collaboration and information sharing among operators, where relevant, and between operators and suppliers. Statoil, under pressure from its competitors and learning from its suppliers, would be more inclined to fully embrace continuous improvement/incident reporting regimes that reduce risk and allow for efficiency enhancing collaboration. Unions, finally, might find a new or additional role as pillars of the incident reporting regime, giving renewed meaning to the Nordic or Norwegian model of regulation.

But of course it is equally possible to imagine a struggle to defend the status quo frustrating any of these developments, and one stalemate producing others. Deeper knowledge would only sharpen understanding of both possibilities.

7. Local questions and the global trend

The foregoing points to broad and coordinate trends in the organization of production and in regulation. Developments in Norway help substantiate the general claim that, faced with uncertainty, industry and regulators are moving to adopt incident reporting systems to foster learning and improve performance through experimentalist scrutiny and revision of organizational routines. The increasingly collaborative nature of production—reflected in the mutual dependence of service providers and platform operators in the Norwegian oil and gas industry—and the ineliminable role of human or organizational factors in catastrophic risk suggest that ex ante or pre-authorization attention to risks must be complemented by attention to risks that arise ex post, after regulatory approval of products or processes.

But the Norwegian case also shows that however general the pressure for adjustment to uncertainty, the diffusion of incident reporting, even as a best practice, is not spontaneous or automatic. Persistent private efforts at self governance show that firms are aware that they, like the regulator, are ignorant of the emergent risks. But these efforts are fragile; they are unlikely to be institutionalized without the intervention of a meta-regulator capable of fostering and supporting on-going collaboration and learning among private actors. As the dilemmas confronting not only the PSA, but the NOG and the unions as well, show,

lingering hierarchy, rigid role understanding and the politics surrounding the protection of both can hamper recursive learning.

Perhaps the most general and encouraging—but also sobering—lesson of Norwegian experience is that the organizational resources required for this kind of continuous collaborative learning are often generated by the very forms of collaborative production that lead to the co-production of catastrophic hazards: The same ways of working that endanger us enable us to master the danger. Concretely, the efficiency gains of the new production consortia go hand in hand with increases in personal as well as process safety.

Thus to judge by developments on NCS, even under the harshest conditions the newest and most complex technology has not escaped our control. We can learn to understand the risks we create, and we can institutionalize that learning in new kinds of regulatory oversight. For better or worse we are still the sorcerers, not the sorcerer's apprentice, and responsible for what we make of our powers.

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