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

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1. Introduction

As production becomes more collaborative, involving key suppliers of complex sub-systems and services in design and production, products and production methods become more innovative but more hazardous. Collaborative production by supply chains connecting independent specialists is highly innovative: Unlike the captive component makers of vertically integrated firms they displace, independent suppliers learn rapidly from pooled experience with a wide range of customers; close cooperation between these competent suppliers and final producers allows rapid improvement in the designs of each. But this innovative recombination of knowledge 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, and again over a period of years, with faulty ignition switches, so that the airbags were deactivated just as crashes occurred. Ingredients contaminated with pathogens are periodically introduced into global food supply chains; the pathogens are widely propagated as the adulterated foodstuffs are incorporated into diverse batches of final product and the processing equipment itself is contaminated. Breakdowns in communication between energy operating companies, drilling rig contractors and suppliers of oil-field services such as cementing 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 year of service because of electrical system problems originating in a faulty lithium-ion battery supplied by a Japanese manufacturer.

The inadvertent co-production of hazards by independent firms—many identifiable only years after products have entered commerce—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 the problem of regulation has been an information asymmetry: Firms know more about the risks they generate and the costs of mitigating them than do regulators, and have incentives to make strategic use of their superior information to frustrate

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costly supervision. The task of the regulator 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 control of regulation to its addressee.

Under uncertainty, however, neither the regulator nor the regulated firms know 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 new task of the regulator under uncertainty is twofold. First it must induce and if need be help organize firms’ systematic efforts to improve their capacity to identify and address risks that can be anticipated by careful canvass of current experience: Firms are required, for example, to present a plan specifying the risks of proposed operations; how those risks will be mitigated; the tests by which the effectiveness of the mitigations will be verified; and the methods for recording test results.

But recognizing the fallibility of all such efforts, the second regulatory task is to induce and support 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 the countermeasures to ensure the safety of current operations are in fact 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 risks in light of the shortcomings revealed by the efforts to address them.5

A few regulatory systems with one or the other of these two 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 deterioration of equipment to disruptions of power generation 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.6 Following the explosion in

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6 Rees, Joseph V. Hostages of each other: The transformation of nuclear safety since Three Mile Island. University of Chicago Press, 2009,pp 23-50. The operation of the event reporting system is the joint responsibility of the NRC and the Institute of Nuclear Power Operations (INPO), an independent entity formed by the nuclear power industry after the accident at the Three Mile Island nuclear power plant in 1979. For the division of labor between the NRC and INPO and the close
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 have required 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 exceptional events such as changes in goals or methods or dangerous failures.7

But such regulatory systems long seemed to be exceptional responses to distinct and manifestly hazardous technological constraints of just the kind found in nuclear power generation or off shore drilling in harsh environments: complex, continuous process operations with interdependent or “tightly coupled” subsystems that transmit disruptions rapidly, often in unforeseen and self re-enforcing ways, and—absent special precautions—on occasion with 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 through diffuses much more broadly the kinds of uncertainty formerly associated with a particular class of technology.

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 relying for enforcement on 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 implementation of the new methods, particularly the adjustment of the federal inspectorate to them in slaughterhouses, has been halting and at times ineffective.8 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.¹⁹

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—such as pilots, maintenance workers, dispatchers or flight attendants—report, with assurance of lenient treatment, deviations from standard operating procedures that may or may not be infractions of rules but are almost surely unobservable by either upper level management or the regulator. An event review committee (ERC), consisting of a representative of the carrier, the FAA and the reporting employee’s union, evaluates the reports and when necessary decides corrective action by consensus. In case of deadlock the FAA representative decides. Each air carrier in the program has a continuing analysis and surveillance system (CASS)—essentially a team which reviews the ASAP reports concerning the carrier and draws on related sources, including internal audits, to spot alarming trends or anomalies in operations and the suggest and prioritize remedies. The FAA’s local Certificate Management Offices in turn use ASAP and CASS reports to keep abreast of the carrier’s performance.¹⁰

Between 2004 and 2007 serious incidents revealed that the FDA was neither able to capture information on the adverse effects of drugs it had already approved for use, nor had the authority to respond even when foreign counterparts provided warnings.¹¹ An authoritative review of the FDA’s procedures¹² found that increased pressures and possibilities for innovation, combined with the inherent limits of even carefully controlled tests of efficacy and safety—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 both improved techniques for predicting drug-related hazards, and enhanced authority to operate a post-approval surveillance system. Congress passed the Food and Drug Administration Amendment Act

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(FDAAA) in 2007. The Act gives the FDA authority to require a drug producer to conduct a post-approval study or trial to evaluate the extent of a known risk, to assess preliminary indications of a serious risk, or to use available data to identify a previously unknown risk. More generally the Act requires the cabinet officer supervising the FDA, the Secretary of Health and Human Services, to regularly “report to the Congress on the ways in which the Secretary has used the active postmarket risk identification and analysis system ... to identify specific drug safety signals and to better understand the outcomes associated with drugs marketed in the United States.”13 But despite substantial progress meshing the units responsible for pre- and post-approval monitoring,14 there are conspicuous gaps in the information reporting system and, as in food safety, worrisome delays in generalizing the results of pilot projects as new institutional routines.15

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.16 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 systems of error detection that delayed identification of the interaction between the then new air bags and the defective ignition switch for a decade is from this year.17

Finally, the British Financial Conduct Agency, responsible for overseeing the protection of consumers in financial markets, notes in recent guidance that the originator of products 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.”

The new Agency appears to be making aggressive use of its powers.  

While this quickening drumbeat of new style regulatory activity attests the pervasiveness of uncertainty related to collaborative production, the manifest difficulties in implementing new arrangements also reflect the contradictory bundle of incentives for both firms and administrative authorities facing the new circumstances. Increasing uncertainty reduces information asymmetries, thus diminishing firms’ strategic advantage over the regulator and increasing the returns of cooperative hazard identification. Firms, moreover, are linked not only by shared suppliers, but also by common interests both in avoiding disasters that taint the reputation of all and in learning from the experiences of others before encountering problems on its own. These incentives too favor cooperating in the construction of risk identification and incident reporting systems.

But when it comes to the practicalities of doing so firms’ incentives may diverge. Especially 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. Much less capable firms may resist exposing their vulnerabilities to outside scrutiny, and prefer to work against new regulatory requirements with which they may not be able to comply. Trade associations, representing firms along the whole continuum marked by these extremes, will be pressured both to help organize incident reporting and other collaborative investigations of emergent hazards, but pressured against actions that could create new obligations for the unwilling.

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20 All of these motives contribute to the well-documented sense, especially among large, transnational firms, that they operate with a “social license,” and that gaming regulatory compliance puts this license in jeopardy. See Gunningham, Neil, Robert A. Kagan, and Dorothy Thornton. “Social license and environmental protection: why businesses go beyond compliance.” Law & Social Inquiry 29.2 (2004): 307-341.
21 Given these countervailing pressures it is unsurprising that harm reduction programs administered by trade associations without official oversight or sanctions produce very mixed results. Perhaps the best studied case is the Responsible Care (RC) program established by the American Chemistry Council to reduce the risks of toxic releases after the gas-leak explosion of a Union Carbide plant in Bhopal, India, in 1984, which exposed some 500,000 persons to a toxic gas. For evidence that RC has been ineffective at reducing pollution, see Gamper-Rabindran, Shanti, and Stephen R. Finger. "Does industry self-regulation reduce pollution? Responsible Care in the chemical industry." Journal of Regulatory Economics 43.1 (2013): 1-30; for evidence that it has nonetheless been effective in reducing industrial accidents, see Finger, Stephen R., and Shanti Gamper-Rabindran. "Does Industry Self-Regulation Reduce Accidents? Responsible Care in the Chemical Sector." Responsible Care in the Chemical Sector (March 1, 2012) (2012).
Similarly with regulators. Some regulators, and their political constituents, may see cooperation with industry in the construction and operation of incident reporting and related systems as a way to respond to otherwise fugitive developments, and to hold private actors accountable in new but effective ways. Others will see in such cooperation an abdication of public authority to self-governance by private, and selfishly motivated actors.\textsuperscript{22}

But although motives are mixed and interests contend 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 existence, 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 particulars of local 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 regulation based on incident reporting. Norway is particularly revealing in this regard. The industry, though formed relatively recently, was built on hierarchical foundations that make adjustment to collaboration particularly acute and visible. In contrast the regulator, also formed relatively late, was built to address rapid change. It is widely recognized to be independent of political influence; it foresew prescriptive rules and is in that sense post-bureaucratic; it complements oversight with strict rules assigning liability to private actors. At least as seen from the perspective of much US discussion of regulation, adjustment under these conditions should be automatic and almost effortless. That it is neither suggests important limits to that debate. More importantly, the convergent and increasingly systematic efforts by firms and the industry to construct an incident-reporting regime demonstrate the complementary pressures on both to address uncertainty through collaborative learning.

Take first industry: Production on the Norwegian continental shelf (NCS) began in the 1970s and was dominated by a state-owned, national champion—Statoil. An aggressive, successful industrial policy favored technology transfer to it. The privatization of Statoil in the 1990s, and a general substitution in those years of market relations for state direction in response to concerns about bureaucratic management, improved efficiency for some time, but also induced concentration in the supplier industry and left unaltered Statoil’s dominance of it. Since the turn of the millennium the increasingly innovative Norwegian supplier industry has successfully globalized, while Statoil and other established producers on the NCS, burdened by internal rigidities and difficulties in coordinating with their suppliers, have struggled to deploy the most current and efficient technology. These difficulties have left room for the entrance into the industry of new forms of consortia in which groups of operators and suppliers collaborate closely with each other to achieve significant increases in drilling efficiency without jeopardizing safety.

The PSA has followed a similar trajectory from early success to bafflement and some disorientation in the face of new circumstance. By many measures the PSA and its predecessors have been extremely successful. Since the Alexander L. Kielland semi-submersible rig capsized in the Ekofisk oil field in 1980, killing 123 persons, there have been no disasters on rigs on the NCS. Aggregate statistics show a long-term reduction in important risk factors such as the frequency of small hydrocarbon leaks. Part of the explanation for this success is the separation in Norway, since 2004, between authority to supervise leases to oil company operators, lodged in the Norwegian Petroleum Directorate, and authority, housed in the PSA, to regulate matters of health, safety and the environment in oil production. This separation ensures that decisions regarding the latter are not undercut by the drive to maximize state revenues from the oil fields.

Another part of the explanation is the PSA’s avoidance of bureaucratic rigidities in both its internal organization and the form of regulatory guidance it provides. Decision making in the review of the performance of large operators and other important matters is typically by teams. Nor does the PSA produce the normal output of a rule-making bureaucracy: rules. 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. In its insistence that operators alone bear the ultimate responsibility for securing the safety of their operations and protecting against environmental harm, the PSA complements its supervisory powers with a public law variant of strict liability. Because it is the operator, not the regulator, who has the duty to search continuously for the best available solutions to HSE problems, the Norwegian authorities speak of a system of “internal control.”

The PSA’s independence from industry and flexibility in rule making are both buttressed by the participation of strong oil – industry unions in a tripartite system of problem identification and resolution. 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. The Norwegian example played an important role in the decision to reallocate leasing and regulatory powers, initially combined in the US Marine Minerals Service, to separate authorities after the Macondo blowout.

But on closer inspection operations on the NCS are more catastrophe-prone than first appears, and for reasons rooted in the same kinds of coordination problems that hinder efficient production by operators and suppliers. In May 2010, almost exactly a month after Deepwater Horizon exploded as gas from the reservoir rose to the platform during cementing of the well, there was a similar influx of gas at well C-06 in the Norwegian Gullfaks field. Had a favorable wind not dispersed the gas, the outcome would have been catastrophic. The underlying causes of this near miss were strikingly similar to those of another, potentially disastrous incident at the Snorre A platform in November, 2004. Failures of information management within the operating company and between it and its suppliers—the same kind of problem at the root of the shortfalls in efficiency and innovation—were implicated in both. Far from learning from the Snorre A incident how to both help and oblige firms to address such safety-critical coordination problems, the PSA seems to have contributed, through well intentioned but fitful demands for improvement without accompanying support for capacity building, to a succession of flawed reform efforts by companies. A profusion of rules and procedures ultimately made coordination more, not less difficult. Put more generally, independence and flexibility are necessary but not sufficient conditions for regulatory success under current conditions.

Both the PSA and the industry—through its trade association, Norwegian Oil and Gas (NOG)—have been responding in the last decade with increasing urgency to the risk of catastrophe crystalized in these near misses and discussed broadly in investigations and reports they have triggered. The PSA has organized investigations of the causes of hydrocarbon leaks, conducted surveys of the integrity of operating wells, begun to collect data on shortfalls in safety-critical

\[24\text{ See Lindoe, Baram, Renn Risk Governance of Offshore Oil and Gas Operations, ibid for the case for Norway as best practice}\]
\[26\text{ SNA 28.11.2004 den alvorligste hendelsen på norsk sokkel etter 2000--iris report, p 34}\]
maintenance, and started to draw attention to persistent disparities in the performance of the safety management system of different firms.

The NOG, focusing more and more directly on firms’ need to learn from each other about emergent hazards and possible responses, has organized fora for categorizing and analyzing the causes of hydrocarbon leaks, losses of well control during drilling, failures of integrity during well operation, and problems arising during the plugging and (temporary) abandonment of wells. The upshot is an incipient incident reporting system—incipient because participation is voluntary and therefore incomplete, and because companies can likewise decide to respond or not to incident reports at their own discretion. In principle the PSA could make participation and response obligatory by redefining firms’ existing obligation to maintain adequate safety management systems. But doing so would require the agency to rethink its own role under the internal control doctrine, shifting or extending the focus of monitoring from individual firms to the industry as a whole, and actively supporting the reinforcement and extension of the emergent institutions for incident reporting, analysis and response.

Norwegian developments thus help us better understand how uncertainty prompts more and more rigorous collaboration among firms, and between the firms and the regulator, in identifying emergent risk. But these same developments also highlight the political and organizational difficulties that might obstruct such collaboration, and hint at possibilities for surmounting them.

The remainder of this paper is in seven parts. The next reviews the literature on regulation and on the hazards associated with complex, highly interdependent forms of production, underscoring the lack of connection between them and the inattention of both to the kinds of information pooling and learning that are becoming increasingly central to production and regulation. Part 3 presents the current Norwegian regime, beginning with the emergence of the oil and gas industry on the NCS and the reorganizations that improved efficiency while conserving hierarchies within and among firms that subsequently hampered development. Then it surveys the key features of the current regulatory regime, especially the internal control doctrine that the PSA interprets as limiting its responsibility to detecting, by close and careful monitoring, shortfalls in safety performance of major operators, without providing them individually or together assistance in building the capacity to respond. Part 4 details the increasingly apparent costs of this regime, beginning with shortcomings in regulation, then presenting evidence of the industry’s decreasing capacity to absorb innovative technology, and even maintain historic efficiency levels, and of the links between these outcomes and underlying coordination problem. Analysis of the Gullfaks C near miss shows how the limits of industrial organization and regulatory arrangements can be mutually, and dangerously, re-enforcing. Part 6 looks to signs of industrial renewal in the emergence of new consortia that outperform incumbents through close coordination among the participants, and to signs of regulatory renewal 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 7 presents some of the chief obstacles to consolidating the emergent system of production and regulation and then speculates on the possibilities for overcoming them both in Norway and more generally.

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, such as the Macondo blowout, is, with a few, important exceptions, disjoint. There is a literature in economics that focused first on problems of capture, then—abandoning hope in the oversight capacities of bureaucracies—on market-based mechanisms for addressing problems of pricing in networks and other interconnected production systems. But that literature ignores the organizational hazards that such interconnection creates. There is a dated debate in organizational sociology on the relation between complexity and catastrophe: the pessimists hold that the tendency of modern technological development is towards systems too complex to control safely; the optimists point to counterexamples to demonstrate that organizations can avoid catastrophe by inculcating a culture of vigilance. But on closer examination 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 and regulatory organization. This gap is only partially bridged by some thoughtful studies of regulatory innovation. We review these debates here to highlight and clarify the assumptions of our approach in contrast with more familiar ones, but with no pretense to resolve the disagreements we engage. For brevity’s sake we omit discussion of regulation of labor and other conditions in global supply chains—“beyond the state”—through private standards and codes of conduct, except to note that here, too, a shift towards more collaborative forms of production is favoring the emergence of new (and more effective) forms of regulatory supervision.28

Economists in the US turned to the study of regulation in the 1960s and 70s, as the sector-specific, New Deal agencies reached their apogee and began their decline. The public charge of these agencies was to ensure orderly and fair competition within their jurisdictions 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 surmised and documented, regulated firms used political influence to ensure that legislation or the administrative agency responsible for applying it favored incumbents, most directly and effectively by restricting entrance to the industry.\textsuperscript{29} The returns on 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 came to be synonymous with incumbency protection.

As these sector-specific agencies were dismantled or reoriented beginning in the 1980s—in part a response to the criticism of capture, in part an early recognition of the dis-integration and reorganization of industry that would give rise to cooperative production decades later—the focus of regulation was shifting 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 decidedly less rewarding because the new rules did not distinguish between insiders and outsiders, but rather applied to all engaging in certain kinds of conduct. The goal of regulated entities shifted from seeking preferential treatment to relaxation or evisceration of the rules to be applied to all: de-regulation.\textsuperscript{30}

Economics too shifted focus in the 1980s and 90s, abandoning the study of regulation as a special topic in political economy—the sale and purchase of influence—and re conceptualizing it as an instance of the broader class of problems inherent in principal-agent relations: the principal must incentivize agents to execute her plans, but must also induce agents to reveal private information about the costs of alternative actions, without which it is impossible to devise efficient incentives. This reconceptualization directed attention away from regulation as institutionalized oversight and towards regulation as a set of market mechanisms such as contracts and auctions for eliciting the information necessary for optimal decision-making.\textsuperscript{31}


\textsuperscript{30} This account follows the incisive pr\'{e}cis of developments in Posner, Richard, “The Concept of Regulatory Capture: A Short, Inglorious History”, in Carpenter, Daniel, and David A. Moss, eds. *Preventing regulatory capture: special interest influence and how to limit it*. Cambridge University Press, 2013, pp 57-68.

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 take the optimal level of precaution.\(^{32}\) But as noted above, and as we will see in more detail below, Norway, for one country, already has in place liability rules of the intended kind, without achieving the expected results. In contrast, the monitoring regimes that Norway and other countries are constructing in response to the insufficiency of liability rules are nearly invisible from the economists’ principal agent perspective.

Nor does discussion in 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.\(^{33}\) They result from the rapid and unforeseeable propagation of disruption through interacting subsystems of the kind 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.\(^{34}\) Safety, the argument continues, is a matter of operator behavior and disposition: Operators who are preoccupied with the possibility of failure, attentive to “weak signals” of disruption and willing to rely on experience avoid accidents, not least by knowing when to disregard bureaucratic rules.\(^{35}\)

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. On the contrary: 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. Moreover, neither the nuclear power plants at the heart of NAT or the air traffic control systems that inform HRO are subject to the kind of 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” 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 large measure because of increased collaboration between Russian operators and their foreign counterparts, organized under the auspices of the World Nuclear Operators Association; the reactor meltdowns at Fukushima resulted from failure to design against an exogenous event—a tsunami—rather than the inherent complexity of the installation.) Moreover, as we will see from Norwegian experience, there are dramatic and persistent differences in the capacity of different firms to control the occurrence of the various classes of precursor events that concatenate in highly interdependent systems to produce catastrophes. It is clear from incident or accident reports that near misses there (and catastrophes elsewhere) are invariably preceded by ongoing failures of the systems managing such events. 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 standalone 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 development of the attitudes and dispositions associated with a safety culture: Incident reporting systems and the investigations they trigger foster vigilance, and vigilance supports the operation of the reporting regime.40

A more recent approach, meta regulation, is rooted in the study of regulation itself, rather than in the disciplinary concerns of economics and sociology.41 It anticipates key aspects of the recursive model under discussion here, especially the changed role of the regulator. Rather than presuming to write uniform rules based on scientific study and such information as industry can be incentivized to provide, the meta regulator instead aims to induce heterogeneous ground-level actors—firms—to engage in the active investigation of the particular risks they face and 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 supervisory responsibilities of the regulator.

For management-based regulation, for example, firms in many industries are heterogeneous simply because of their technical and managerial idiosyncrasies. If in addition it is impractical to observe the regulated conduct directly and sanction non-compliance, regulators cannot hope to write rules that apply effectively to all. Moreover, in such settings the idiosyncrasies of production are likely to be such that management itself may well overlook cost-efficient possibilities for reducing harms. In response to 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 provisions of the Massachusetts Toxics Use Reduction Act (TURA) of 1989, is that planning and execution are complements: Placed under the obligation to prepare plans for reducing the use and production of toxics or other environmentally harmful substances firms will discover opportunities for affordable, perhaps profit maximizing improvement that the regulator could not have

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40 For a careful study of the persistent but failed efforts to conceptualize the idea of a stand alone safety culture in an institutionalizable form in the Norwegian offshore oil and gas industry, see Kringen, Jacob. “Culture and control: Regulation of risk in the Norwegian Petroleum Industry.” (2008).
anticipated but management will have overlooked; the discoveries will make the plans self executing even though there is no formal requirement to act on them.\textsuperscript{42}

But in the absence of any obligation to enact plans and report on their results, recursive improvement of the regulatory system is only possible if the planning exercise itself touches off a self-sustaining cycle of planning and correction in individual firms. This proves not to be the case. In a careful study of environmental performance in Massachusetts and the 13 other states that adopted management-based regulation similar to TURA, Bennear found that pollution prevention planning reduced toxic releases by 30 percent—but only for the six years following adoption of the statute.\textsuperscript{43} The planning obligation does in short reveal unexpected opportunities for improvement but does not lead to the kind of recursion that can make improvement continuous.\textsuperscript{44}

The model of responsive regulation proposed by Ayres and Braithwaite, in contrast, sees heterogeneity in the disposition of actors to comply or not with regulatory obligations. The focus accordingly is on the optimal allocation of regulatory attention between good and bad types. In the model the regulator can achieve the optimum by playing tit for tat with firms: cooperative or compliant firms that make good faith and successful efforts at risk reduction get little attention, while uncooperative ones get a lot. But the cost of this kind of optimization is that regulators and other firms cannot learn from the good practices of the most successful cooperators.\textsuperscript{45}

The recursive or experimentalist model differs from these in emphasizing the importance of uncertainty, and with it the need for collaborative investigation by


\textsuperscript{44} For this and related reasons Bennear discards management-based regulation as an effective response to the kinds of risks that produced the Macondo blowout, and favors instead a system of experience-rated safety deposits, to be refunded in case drilling is completed without incident. See Bennear, Lori S., "Beyond Belts and Suspenders: Promoting Private Risk Management in Offshore Drilling, in Coglianese, Cary, ed. \textit{Regulatory Breakdown: The Crisis of Confidence in US Regulation.} University of Pennsylvania Press, 2012.

firms of the emergent risks they face and 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 flows of information about firm conduct and capacity that such a regime produces, a meta regulator that responds effectively to uncertainty will also be well equipped to address the problems of heterogeneity of firm type and technical set up, 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 family of meta regulation in which the meta regulator, faced with uncertainty, has responsibility for supervising and if need be helping to organize both the evaluation of pooled risk reduction plans and a system of incident reporting to avert immanent harms and update understanding of risk.

3. The Emergence of the Current System

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

During the 19th and early 20th centuries, Norway pursued a form of industrialization based on natural resources similar to that in the other Nordic countries, and larger countries such as Canada, the US and Australia as well. 

46 Fishing, shipping, ship building, meat and dairy intensive agriculture, mining, forestry and small scale mechanical industries related to those endeavors flourished through a creative mixture of small holder entrepreneurialism and cooperation. The development of hydroelectric power at the end of the 19th century encouraged the development of a further array of industries in which much larger, but still rurally based, firms used the new power source to exploit local raw materials in the production of aluminum, ferro steel, paper, and chemical fertilizers. The Norwegian state supported these new ventures by encouraging indigenous scientific and technological research and opening the country to foreign investors willing to transfer compatible technologies into the Norwegian economy. Norwegian industry researchers were pioneers in climatology, fish demography, small ship motor technology, fertilization and hydroelectric power.

When oil was discovered on the North Sea Shelf and Norway entered the oil and gas industry in the 1960s and 70s the state took a more active role. Instead of the


supporting bottom-up, private initiatives, the state undertook to develop the industry in the interest of Norway’s competitive future. The global oil industry was at the time dominated by a few giant multinational companies, and virtually no know-how for either oil exploration or production existed in Norway itself. To develop the North Sea oil for Norway, the government sought to attract foreign producers into Norwegian waters on terms favorable to the country, while also encouraging the development of indigenous firms. The result was what proved to be a very successful infant industry strategy of dynamic protection and technology transfer.

There were three prongs to this development strategy.\(^\text{48}\) First, the state shrewdly managed its concession’s system, giving foreign MNCs access to Norwegian reserves on terms that not only ensured favorable returns to Norway (through leases and taxation), but that also required producers to use Norwegian suppliers for the construction of the drilling platforms and transport of materials and product to and from the wells. Second, the state created its own oil company, Statoil, and then allocated extremely valuable concessions to the company, while simultaneously luring international technology suppliers into deals with the new company that transferred know how and technology both to Statoil itself and to key Statoil suppliers, such as the private companies Aker and Kvearner.

In combination these two prongs succeeded in launching the Norwegian oil industry in the 1970s and 80s, and directed it towards use of a distinctively Norwegian technology—Concrete Deep Water Structures or Condeeps. The Condeeps were heavy, gravity stabilized platforms capable of withstanding the great depths and turbulent seas in the North Sea drilling environment. Their construction made it possible to redeploy and develop longstanding Norwegian know-how with concrete (developed in the hydroelectricity generation business), as well as deep reserves of knowledge and experience in marine engineering and shipbuilding. The North Sea was the only oil-producing region to use this technology; it became the exclusive platform for Norwegian exploration and production. Producing these gargantuan constructions helped save the Norwegian shipbuilding industry, which had fallen into crisis in the 1970s, and generated substantial employment in Norway for over two decades.

The third prong of the Norwegian oil industry development strategy was the use of so-called “Good Will Agreements” with global oil majors and the multinational oil-service suppliers. Once development on the NCS was underway, and indigenous Norwegian producers established, the Norwegian state attempted to stimulate the development of technology within Norway by granting international companies attractive leases on the North Sea shelf and contracts with Statoil on the condition that they invested in R&D with Norwegian suppliers and in projects at Norwegian

\(^{48}\) The following account is taken from Ole Andreas Engen, “The Development of the Norwegian Petroleum Innovation System: A Historical Overview” in Fagerberg, Mowrey and Verspagen, eds., *Innovation, Path Dependency and Policy: The Norwegian Case*, pp 179-227
technology institutes. In this way new technology and production know how was directly transferred into Norwegian firms and into the Norwegian training system.

By the mid 1980s, the Norwegian Oil industry had become profitable and Norwegian firms, particularly Statoil, the key suppliers Aker and Kverner and an array of small supply ship manufacturers along the west coast of Norway had become internationally competitive technology producers. When the new Gullfaks field was opened in the early part of 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.

This success, however, occurred during a period of relatively high global oil prices that allowed the Norwegian companies to generate profits despite comparatively high labor and production costs. As the price of oil fell in the 1980s, these underlying costs revealed structural weaknesses in the industry’s organization, forcing the Norwegian state to abandon many of the top-down bureaucratic practices of the infant industry strategy.

The decisive step was for the state to sharply limit its direct control of the industry and “strongly encourage” the main operators and suppliers to cooperate with one another to lower costs and develop competitive technologies and standards. The result was the formation, in 1993, of Norsk Sokkels Konkurranseposisjon (NORSOK). NORSOK gave the oil companies and the main suppliers greater freedom to design contracts, pursue new technologies, and choose sub-suppliers and drilling locations. The main goal was to introduce flexibility into what had become highly bureaucratized relations and thereby, to reduce the cost level on the NCS by 50 percent.

The NORSOK players agreed that achievement of these goals required simplification of the highly fragmented and inefficient contractual landscape between the state, Statoil and the many suppliers in the supply chain. The operator’s responsibility for project management and technological development was decreased and that of the main suppliers, such as Aker and Kvaerner,

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50 There was an initial shock—between 1981 and 1985 the prince of oil fell from $40 per barrel to $9. But the real pressure came from the new much lower level of stabilization. From 1987 to the mid 1990s, the price of oil fluctuated between only $17 and $25/barrel (Engen p 196)
increased through the proliferation of encompassing Engineering Procurement and Construction (EPC) contracts. These arrangements gave the main suppliers both the responsibility and the incentive to develop technology and reduce cost. This move did in fact allow for the introduction of many new technologies and organizational practices in to the industry. In particular, the industry successfully moved away from its reliance on the Condeep structures and moved into the production and use of more technologically sophisticated floating drilling platforms, production vessels and sophisticated automated subsea technologies. But the move also produced significant price competition among the few main suppliers and corresponding efforts by them to squeeze sub-suppliers further down the value chain. A shakeout ensued that ultimately resulted in the merger of the two main suppliers, Aker and Kvearner, and to the entry of highly sophisticated global systems suppliers and specialists into the Norwegian industrial arrangements. The top down bureaucratic infant industry system was in this way replaced by a more market-based, but still hierarchically organized system that privileged operators over main suppliers and main suppliers over sub-suppliers.

As part of the strategy of markedly reducing its control of the industry the state privatized Statoil in 1991 and then approved first the takeover by NorskHydro of Saga, a smaller operator, in 1999 and then of NorskHydro itself by Statoil in 2006. Thus, the bureaucratic control mechanisms centered on the state were over the course of the NORSOK process replaced by intense competition among the operators and suppliers, resulting in a restructured, technologically more sophisticated and competitive—but also more concentrated—industry. But as we will see, many of the essentially hierarchical forms of organization, both within the large operators and established by contract in their relations to major suppliers, that helped solve coordination problems in the NORSOK era have proved to be obstacles to coordination under current circumstances. They generate problems within the supply chain and significantly limit the ability of Statoil and other Norwegian operators to incorporate emerging technological and organizational innovations.

3.b Functional Regulation, Internal Control and Acknowledgment of Consent

The Norwegian off-shore regulatory system consists of two disparate complexes. The first, centered on the PSA, aims at the articulation of formalized procedures at high levels, even if the Agency itself scrupulously avoids the promulgation of fixed and formal rules. The second, centered on relations between unions and

52 Arthur Stinchcombe and Carol Heimer, *Organization Theory and Project Management. Administering Uncertainty in Norwegian Offshore Oil*, (Oslo: Norwegian University Press, 1985) saw the problems faced by the Norwegian offshore industry in the 1980s as deriving from “the late and irregular delivery of engineering decisions to the owner, and through the owner to the builder, which creates … cost and schedule difficulties.” The proposed remedy was to administer the linked activities “under one authority”—in effect the solution pursued in the NORSOK regime. See ibid, p. 32.
management, focuses on setting 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 two are imperfectly integrated at best, in tension or at odds at worst, and the increased vulnerability of the regulator and the industry will, at least for a time, increase the tension.

First under the NPD and later under the PSA Norwegian regulation shifted from prescriptive to functional. In the prescriptive or command-and-control regime that prevailed through the 1970s, 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 conditions of intended use. These functional requirements are typically further detailed and elaborated in guidelines or “cookbooks” provided by the regulator or private consultants. The guidelines in turn incorporate by reference domestic and international standards that in some cases provide yet more detail.

Functional regulation is complemented by the operator’s ultimate liability for damages caused, under the internal control doctrine. This means that even if a regulated entity undertakes to meet the requirements of functional regulation by complying with guideline specifications and standards, it must still, in theory, actively examine the possibility that there may be a better way of meeting its obligations; and if it chooses an alternative to the indicated solutions it must justify its choice to the authorities.53

In addition the internal control doctrine has been read together with several statutes regarding workplace safety to imply an obligation on the part of regulated entities to institute safety management systems.54 These systems establish company-specific norms to ensure safe operations, and routines for ensuring that these norms are enacted. Increasingly the PSA checks compliance by examining the scope and reliability of these safety management systems rather than by direct inspection. But again creating a “compliant” safety management system does not relieve the operator of liability for damages. Regulations impose an overriding, continuing duty

53 Kassen, “Safety Regulation on the Norwegian Continental Shelf”..., pp. 105 ff. This is a variant of the “comply or explain” obligation common in the corporate governance law of many EU member states. See Financial Times, FT.com/lexicon, definition of “comply or explain,” at http://lexicon.ft.com/Term?term=comply-or-explain
54 WEA, Section 2 a: “The employer shall systematically plan, direct and control activities in a manner which leads to the working environment meeting the requirements for a good work environment. He shall investigate work injuries, continuously investigate the hazards of the activity and take the measures thus prompted. Measures which cannot be taken immediately shall be timetabled……To the extent which the activity requires, the employer shall document the working environment and measures to improve the same. Action plans shall be drawn up in this connection.” http://www.legislationline.org/documents/id/3702
on the operator to “see to it that everyone who carries out work on its behalf, either personally, through employees, contractors or subcontractors, complies with requirements stipulated in the health, safety and environment legislation.”55

In the same spirit the PSA does not officially approve applicants to operate that meet all requirements; still less does it issue an operating permit. Instead, it issues an “acknowledgment of compliance,” which, underscoring that permission to operate is provisional, and the Agency’s refusal to endorse any solution officially, is defined as follows:

An acknowledgement of compliance (AoC) is a declaration we [the PSA] issue to express our confidence that petroleum operations can be pursued by a mobile facility in compliance with the regulations. We base this decision on information provided in a separate AoC application about the technical condition of the facility and the applicant’s organization and safety management systems.56

As usual in these kinds of regulatory systems individual operators may be subject to particular requirements, especially when audits or other forms of supervision reveal shortcomings in their safety performance. In fact, the PSA maintains dedicated, multi-functional teams that monitor the performance of the major operators and suggest, with increasing threat of substantial penalties if need be, areas for (urgent) improvements in current organization.

In light of the growing role of the fora organized by the NOG in shaping regulation it is important to note that collaboration between industry and the PSA is hardly unprecedented: from the mid-1990s on, and probably well before, bodies convened by the NOG had an active part in shaping the current AoC regime. Sometimes this was done through standard setting. For instance, an industry group established, and revised, minimum standards for well control training including reference to relevant international standards and the PSA then incorporated the industry’s standard in its guidelines. But on occasion the interventions led to revisions in the conditions for obtaining the AoCs themselves. For instance, the PSA, in accord with the understanding of internal control as imposing liability directly and exclusively on operators, originally accepted application for AoCs only from them. Drilling contractors, who actually bored the wells, had to submit the details of their equipment and procedures to the operators, who included these in their applications to the PSA. But using the operator as the intermediary for discussions

56 http://www.psa.no/what-is-an-acknowledgement-of-compliance/category952.html
between the contractors and the regulators was burdensome and ineffective. Eventually a group of contractors, again under the auspices of the NOG, agreed on a division of labor with PSA by which the operators would apply for AoCs covering the area- or well-specific aspects of a project, while the contractors would apply for AoCs covering the rig and procedures to be used in drilling.

But perhaps the most significant and promising collaboration between the PSA and NOG occurs in connection with the preparation and use of the annual report on *Trends in risk level in the petroleum activity* (RNNP) that the Agency has published since 2001. The report uses the incidence of defined hazard and accident conditions (DFUs), such as low-level hydrocarbon leaks, to track changes in the level of personal injury and catastrophic failure risks in the industry as a whole. By reporting this data the RNNP performs a useful signaling function, alerting the PSA, industry and the public to alarming or encouraging developments and, in case of alarms, triggering further inquiry: Concern with hydrocarbon leaks (whose incidence had been rising in the years before the RNNP was established) led to the formation of a working group under NOG auspices to investigate further and propose responses. The list of risk indicators is, moreover, open-ended; the PSA, responding to developments, considers introducing new ones from time to time. In 2006, for instance, the PSA conducted a pilot survey of well integrity—defined as maintenance of two barriers against leakage between the well the surrounding formation—among seven operators on the NCS, and found that 18% of production wells were impaired. The RNNP now includes a traffic light rating of well integrity—green for two functioning barriers, red if both are impaired, with yellow and orange marking intermediate stages of deterioration—and the NOG has established a well integrity forum in which operating managers from key companies report incidents and remedies. Since 2010 the PSA has collected data on backlogs in preventive and corrective maintenance from firms and published the results in the RNNP. The RNNP thus creates a forum in which the PSA can raise and NOG can respond to emergent concerns regarding the potential for catastrophe: It allows for creation of new, loosely collaborative institutions with no clear place in the current regulatory model—perhaps indeed foreshadowing a new one—yet without obligating either party to address, at least for now, the possible

57 http://www.2psa.no/about-rnnp/category911.html
59 PSA, Petroleumstilsynets undersøkelse vedrørende brønnintegritet i 2006: Bakgrunn & resultat fra fase1, samt intensjon for viderefering av fase 2, Sikkerhetsforum, December 6, 2006.
implications of their actions for the division of labor and jurisdictional responsibilities between them.  

Alongside, and entwined with this complex of internal control and safety management was established a tri-partite regime of labor-management cooperation under state auspices. The Working Environment Act of 1977 established the right of employees to halt work upon detecting an immediate threat to health and well being of the workforce, without incurring any liability for the economic loses caused by the stoppage.  This led to extensive collaboration between safety managers and worker safety representatives to address pressing issues at the workplace level.

Collaboration at the national level came in the following decades, first with the establishment of the external reference group on regulation (ERR, now the Regulatory Forum), with the participation of the major employers groups and unions, and a general mandate to consult in the formulation of regulations, for a period in monthly meetings chaired by the NPD. The Regulatory Forum is seldom mentioned in discussions of current policy. Attention now focuses instead on two, more specialized tri-partite fora established subsequently: The Safety Forum was set up in 2000 to discuss matters bearing on health and safety, but not collective bargaining, with the regulator. The PSA regards it as a setting to develop the trust and mutual understanding between management and labor that are the informal foundations for formal compliance with regulations. A year later NOG formed Working Togethers for Safety (SfS), which extends beyond unions and employers associations to include representatives of oil firms, drilling contractors and suppliers. SfS operates through working groups, which identify, harmonize and attempt to diffuse best practices in particular areas—reduction of risks from falling objects, for instance. In its focus on root cause analysis and (regularly updated) best practice responses SfS is, like the well control and other fora, potentially germinating an incident reporting system in production and with it a new model of regulation.

4. The Costs of the current regime

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64 Kringen, Control and Culture… pp 61-71; 80-97

65 Bang and Thuestad, "Governmental Enforced Self-Regulation.." p. 223; Kringen 83-84

66 Bang & Thuestad, p 223; Kringen 83-89
The regulatory constellation organized in the PSA and the tripartite fora has, like the Condeep and NORSOK development regimes, served Norway well. Both have limits that are becoming apparent now as barriers to the reduction of risk and increased efficiency. In this part we look first at these hidden costs in regulation, then in the organization of industry. A close look at the Gullfaks C near miss shows how the limits of each can reinforce those of the other, with extremely dangerous results.

4.1 Limits of self-limitation as a regulatory strategy

Regulation under uncertainty depends on learning, especially by firms: risks that can’t be identified ex ante have to be recognized as potential threats before they are manifest as disasters. But under uncertainty, lacking a reliable map locating opportunities and threats, firms cannot learn from each other in isolation. It is well known that innovation is cooperative: innovating firms collaborate with many partners, and often, indirectly, share knowledge with competitors through the circulation of managers and workers. The need for cooperation is even greater in risk reduction, where eventual hazards, often originating in unsuspected links between otherwise harmless routines, are even harder to identify than emergent opportunities, and where every firm has a manifest interest in learning from the experiences of others before encountering problems on its own.

But the PSA, as we have indicated, does not focus on building an incident reporting system infrastructure for the on-going exchange of information about hazards and their mitigation. Rather, to the extent that it is not occupied by creating framework regulation through the AoC regime, it engages in close monitoring of and dialogue with each of the leading operators. Moreover, far from directing attention to the “operational” risks that only emerge after consent has been given to execute a plan, the PSA encourages a form of quantitative risk analysis (QRA) that aims to reduce the level of known risks at the ex ante, planning stage. Focus on “ex poste” risk is all the more difficult because of the traditional and still influential misconception that reduction of personal injury risk lowers the risk of catastrophe, and the continuing tug of tri-partite fora in the direction of agenda issues with which the central headquarters of the trade unions are particularly comfortable. We comment briefly on each of these to show how they block the emergence of a regime fully capable of integrating safety case planning and continuing correction through incident reporting.

The focus on individual operators. As noted the PSA maintains internal monitoring teams organized around the largest operators. The purpose is to ensure that the Agency develops an understanding of its counterparts that is sufficiently broad, deep and continuous to permit effective oversight. The teams are in regular contact with “their” firms, review the operation and data produced by its safety management system and conduct periodic on-site audits. Systematic problems, once identified, can attract sustained interest. For example, the ratio of corrective to preventive
maintenance 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 is necessary to correct a breakdown that thorough understanding of the equipment vulnerabilities, and the ability to address them could often have prevented. A firm with a troublingly high ratio will be asked to develop and implement a plan to redress the balance.

But these "dialogues" are under current conditions less effective than they once appear to have been, for two closely related reasons. First, the operators are much less central to the actual organization of operations than the system of dedicated teams (and the doctrine of internal control that plainly motivates it) supposes. Operations today are carried out in collaboration between drilling contractors and specialized service providers, with the operator exercising a supervisory function on offshore platforms and, increasingly, on shore. Monitoring the operators closely is to monitor directly only a part, and perhaps not the most important part, of operations. Second, precisely because the operators are dependent on the collaboration of many suppliers over whom they do not exercise anything like complete control, their ability to correct systematic problems by themselves, and often within relatively tight deadlines imposed by the PSA to compel the attention of top management, is limited. The result is that problems are identified but not resolved, and systemic vulnerabilities accumulate. The RNBP for 2013 captures the resulting stalemate clearly. The total backlog of preventive maintenance for all production facilities on the NCS was a little under 10,000, slightly below the level of the year before, but substantially above the level (just above 6,000 hours) for the preceding two years; and the percentage of the total backlog concerning critical equipment was slightly higher than in 2012. The backlog in corrective maintenance in 2012 and 2013 is twice as high as in the two proceeding years. There is, moreover, significant and persistent variation in the maintenance performance among operators. The report notes sternly:

On several occasions, the PSA has emphasized that it is necessary for the operators to assess the volume of outstanding corrective maintenance as a contribution to the overall risk profile for each of the facilities. The reported data for backlogs in preventive maintenance and outstanding corrective maintenance for mobile facilities shows great variation. This is similar to what we have seen in recent years. The PSA wishes to open a dialogue with the industry on this topic....

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The limits of Quantitative Risk Analysis. The PSA puts great emphasis on the need to reduce foreseeable risks as much as possible by the use of QRA. QRA is based on historical data on failure rates: Given its performance in use, a particular part or component is known to fail with a certain frequency under certain conditions. The more of that kind of part used in an assembly or installation, the more likely the ensemble will fail. QRA thus simply extrapolates from the known failure rates of particular parts to estimate the likelihood of the failure of structure that combines various quantities of those parts in novel ways.

There is surely information contained in such analysis, but just as surely not as much as the apparent provision of results and the aura of technical rigor of the analytic process might suggest. There is the problem of domain. 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. To take a crude but effective illustration of the domain 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 data bases on failure rates?

These questions lead directly to a second and more specific limit on this kind of risk analysis: the exclusion of “human factors,” or, more generally, organizational breakdowns as a source of disruption. QRAs assume that parts as designed and built have an inherent failure rate, from which the riskiness of an installation can be derived. But many dangerous outcomes—hydrocarbon leaks maintaining valves, for example—are caused by (organizationally induced) human misuse of equipment. Making the equipment more robust will not by itself make its use less hazardous. 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.\footnote{Skogdalen, Jon Espen, and Jan Erik Vinnem. "Quantitative risk analysis of oil and gas drilling, using Deepwater Horizon as case study." Reliability Engineering & System Safety 100 (2012): 58-66.}

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, plan-stage risk mitigation, as against learning in the ex poste, operating phase, and as such, though not explicitly or intentionally, downplays the role of organizational factors in catastrophe avoidance.
The confusion of increased personal safety with reduction in the risk of catastrophe. The WEA was a remarkably far sighted piece of legislation, obligating employers not only to establish management systems for protecting (and continuously improving protection of) workplace safety, but also obligating firms to afford employees opportunities to participate in the organization of work and otherwise exercise their autonomy. Of the manifold purposes of the Act the one that has been most robustly institutionalized and absorbed in the culture of unions and management is the concern for safety. This concern for safety shades into the conviction that successful management of risks to individuals induces or facilitates broader changes in management—especially more rapid learning from error—that reduces the risks of dangerous failures generally. Convictions of this kind have subtly shaped the PSA’s regulatory priorities and focus.

But in the last two decades it has become increasingly clear that heightened personal safety does not make operations proof against catastrophe. Practitioners and academics have repeatedly stressed that developments in the two domains are only loosely connected, and that it is dangerous, therefore, to use measures of (changes in) personal safety as proxies for trends in what is variously called process safety or asset or technical integrity. For example, a careful review by the US Chemical Safety and Hazard Investigation Board of the causes of the fire at BP’s Texas City, Texas refinery in 2005, which resulted in 15 deaths, states directly: “One underlying cause was that BP used inadequate methods to measure safety conditions at Texas City. For instance, a very low personal injury rate at Texas City gave BP a misleading indicator of process safety performance.”\(^69\) The Baker Report on the same incident is equally emphatic: BP primarily used injury rates to measure process safety performance at its U.S. refineries before the Texas City accident. Although BP was not alone in this practice, BP’s reliance on injury rates significantly hindered its perception of process risk. BP tracked some metrics relevant to process safety at its U.S. refineries. Apparently, however, BP did not understand or accept what this data indicated about the risk of a major accident or the overall performance of its process safety management systems. As a result, BP’s corporate safety management system for its U.S. refineries does not effectively measure and monitor process safety performance.\(^70\)

Academics have also stressed this point. Hopkins, for example, has shown that the Esso gas plant at Longford in Australia had an impeccable lost-time injury rate and

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\(^69\) CSB, p. 19
\(^70\) Baker, p. xiv.
yet was managing its major hazards quite poorly.\textsuperscript{71} He notes that the distinction is well understood in the airline industry, where no one would make the mistake of thinking that an airline’s lost time injury rate provided an indication of how well it was managing air safety.\textsuperscript{72}

All of this is known in the PSA too. Indeed the webpage introducing the 2013 RNNP says clearly “An important aspect of the RNNP process has been a recognition that traditional indicators, such as personal injury statistics, are of limited use in measuring major accident risk.”\textsuperscript{73} But revising the Agency’s priorities accordingly is another matter. Safety management, where safety is still (but no longer uniformly) 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 the career paths of its personnel, many of whom come from or return to positions as safety managers. But beyond these ties, the agency is perhaps inclined to focus on personal safety, and perhaps subliminally hold to the idea of a close association between it and process safety or asset integrity, because of the prominence of this cluster of commitments in the unions and the tri-partite institutions in which they play a leading role.

\textit{The rigidity of the tri-partite model.} As we saw, tri-partite discussion of safety issues has been 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 shifting interest representation from bargaining to problem solving at the national level. More precisely, the problem involves how to connect effective shop-floor and enterprise-level labor-management cooperative problem solving to regional and national levels of coordination and leadership. The difficulties in adjusting to a world of continuous organizational and technical change, especially at the peak level, have deep roots, and the failure to connect local problem solving with the national agenda is recurrent, even if 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 in the other Nordic countries and more generally, inclined to advocacy of 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 the crew of endangered platforms, or, more recently, about fire hose location and design. These disputes take on symbolic significance and raise familiar, politically charged questions—Profits before people? They bear

\textsuperscript{71} Hopkins, 2000  
\textsuperscript{72} Ibid, p 460.  
\textsuperscript{73} http://www.psa.no/rnnp-and-major-accident-risk/category977.html
on matters of fundamental importance\textsuperscript{74}. But however they are resolved, the centrality of such questions to the tri-partite discussions, and the sway of such discussions of the broader regulatory agenda, can re-enforce 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 founding commitments of the Agency, 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 will return to the possibilities for re-orientation below.

5. Pressure on Statoil

NORSOK successfully responded to the legacy problems of the infant industry, especially reliance on Condeep technology, by privatizing Statoil, allowing if not inducing market concentration, and addressing new coordination problems between Statoil—even more than before the dominant operator--and the two remaining supplier groups (and between those groups and their suppliers) by standard setting and encouraging contracts giving the buyer near hierarchical control of the supplier. But the NORSOK regime has legacy problems of its own. As prices and reserves decline the need for performance improvements becomes salient. So too does the mismatch between the organization forms suited to the relatively closed and hierarchically ordered world of NORSOK and today’s world in which the efficient use of current technology and the successful introduction of innovations depend on continuous collaboration among highly capable suppliers, coordinated and facilitated, but not controlled, by the operator. Organizing such collaboration so as to improve both efficiency and process safety is a problem not just for Norway but also for the oil and gas industry world-wide.

Nonetheless, in NOG, the PSA and the Norwegian industry generally there is a sense if not of crisis, then of standing at a crossroads of fateful choices. The Norwegian industry is by some important measures not keeping pace with the world leaders, and, since the industry is central to the national economy, the intimation of economic vulnerability reverberates with concerns of catastrophic risk. The most authoritative documentation of blockages in the organization of the industry is by Petoro, a state-owned company that manages Norway’s portfolio of exploration and

\textsuperscript{74} see Kringen’s discussion of trade union objections to behavior based safety practices, in general and regarding Statoil’s “Safe Behaviour Program”, Kringen, \textit{Control and Culture}, pp 94+ and 267-284
production licenses for petroleum and natural gas – the State’s Direct Financial Interest (SDFI). Petoro exercises its general oversight functions in part through in-depth studies of oil industry performance. Its most recent findings reveal that the Norwegian industry, especially as embodied in 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 stasis is that on average it takes twice as long to carry out 25 representative, routine drilling operations today as it took to execute those same operations in the very same wells roughly 20 years. Figure 1, taken from a Petoro presentation, displays the results.

![Figure 1](image)

In large measure because of this slowdown in operations the number of wells drilled per rig, per year has declined dramatically as well, so the costs of drilling are going up while recovery of what remains of the dwindling reserves is becoming more drilling intensive. The same real productivity declines are captured in increases in
rig days per well, engineering hours per well or per ton, and the number of workers needed to extract a barrel of oil.\textsuperscript{75}

A second, aggravating finding is that even as the industry is taking more time to do utterly familiar things, it is getting slower at adopting new technologies broadly in field use. Figure 2, taken again from a Petoro presentation, displays the nosedive in the national oil industry’s ranking in the league table of technology adopters (where the degree of absorption of new technology is captured by the share of total revenues attributable to equipment on the market for 5 years or less) from 10\textsuperscript{th} in 2005 to 40\textsuperscript{th} in 2013.

\textbf{Figure 2}

This slowdown in the diffusion of innovation is especially puzzling because, as the header in Figure 2 notes, firms on the NCS are “quick to try new technology.” Indeed it would be surprising if they were not, as Norwegian suppliers of capital goods to the industry have established themselves as leading global players in just

\textsuperscript{75} For further discussion of the slowdown in drilling speeds on NCS, measured in meters per day, see Osmundsen, Petter, Kristin Helen Roll, and Ragnar Tveterås. "Exploration drilling productivity at the Norwegian shelf." \textit{Journal of Petroleum Science and Engineering} 73.1 (2010): 122-128.
the period covered in the Petoro graph, and it is hard to imagine that the suppliers could innovate rapidly without local customers who, at least initially, encouraged development of new equipment to meet their own needs, and gave useful feedback about its performance. What then accounts for the broad reluctance of firms on the NCS, especially Statoil, to go beyond this initial, isolated enthusiasm for innovations to their general deployment? What is the relation, if any, between the slowdown in diffusion and the slowdown in the execution of familiar routines?

The Petoro presentation makes little attempt at a comprehensive explanation. Most generally it speaks of “creeping inefficiency” caused by self defeating efforts “to avoid mistakes and create perfect processes,” re-enforced by a corresponding inability to prioritize: “everything appears equally important”. One expression of this creeping inefficiency is “increased complexity” of operations, and a corresponding need for “simplification of requirements, standards and procedures,” which requires “understanding of HSE, operations and business,” capacity “to see the overall effect of individual requirements and initiatives” and “to understand the overall risk reducing effect” of the ensemble of measures. A second manifestation is friction in the relation between suppliers and customers, and hence “the need for operator-supplier cooperation models”-- “suppliers must be given the opportunity to participate” in deploying new technologies.

A more specific conjecture, compatible with Petoro’s explanations, regarding the connection between the slowdown in routine tasks and the reluctance to deploy new technology is this: Much of the new technology makes possible more continuous and precise measurement and control of drilling operations. But whether the technology in use increases efficiency or actually decreases it depends on the level of cooperation between those observing the data flow and those conducting the drilling operation. Consider instrumentation for measuring the vibration of the drilling tool. When the level of cooperation between data observers and operational control is low, the instrument is used to signal situations in which the level of vibrations could jeopardize the tool—to which the operators (following a formal or informal routine) respond by slowing drilling, perhaps below speeds that would have been acceptable in an earlier period, when tool vibrations were not being measured. When the level of coordination is high, however, early indications of a rise in vibration levels touch off a rapid search for ways to avoid reaching levels of vibrations that would jeopardize the tool. Under these conditions the fear of mistakes and the search for “perfect solutions” lead to the proliferation of prudent, but inefficient, rules of thumb rather than cooperative, efficiency enhancing analysis of changing situations. As the sources of (potentially alarming) information increase, so too does 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 whether this more specific conjecture can be substantiated or not, it is clear from the Petoro account, and concurrence from many industry actors, that the high costs stem from coordination problems, and that the latter, generally driven by the factors behind “creeping inefficiency,” are exacerbated by two additional and widely remarked circumstances: the increasing shift of control to on-shore units, which lack the necessary contextual information to make good judgments; and the decreasing tenure of head drill managers on the rigs. What was once the apex of a career is now a stepping-stone to an off-shore management position. Both developments contribute to what Petoro calls a “thinning out of competence,” to which, of course, a predictable response is the attempt to substitute (still more) rules for disciplined, on-the-spot judgment.

Close analysis of the Gullfaks near miss in the next section confirms this general analysis of industry blockages, and in addition calls attention to perverse interactions between the regulator and the firm. Interestingly, this is not—as Petoro and some other industry actors sometimes suggest—through the steady accretion of rules, but rather through failures by both the PSA and managers to establish routines that actually address the organizational problems that both identify as pressing.

5.a The Gullfaks C Near Miss

[This section is still in rough form and will be shorter in the final version. The aim is to convey through a careful analysis of the highly detailed and widely discussed (and PSA sponsored) IRIS report how the limits of industrial organization and regulatory arrangements were mutually, and dangerously, re-enforcing. In any case it will be familiar to many early readers of this paper. Please skip it.]

On May 19, 2010 a breach in the drill casing at the Gullfaks C well allowed drill mud to flow into the formation, which in turn permitted hydrocarbon gas to run into the drill shaft and up to the platform. Wind dispersed the gas, preventing ignition. Without the wind, the incident could have been a disaster on the scale of Deepwater Horizon, which involved a similar sequence of events.

The Gullfaks incident was the third significant accident in the Norwegian North Sea in a six-month period and even more significantly was preceded by a very similar incident at Snorre A on November 28, 2004. This incident was an uncontrolled blowout that resulted in a continuous flow of hydrocarbon gas upwards to the platform. Although the Snorre A incident was carefully analyzed and reforms were proposed, the Gullfaks near miss, extremely serious in itself, seemed even more ominous because it suggested that little had been learned from the earlier event.

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within Statoil or on the North Sea Shelf. For these reasons PSA commissioned IRIS—the International Research Institute of Stavanger—to prepare a thorough report on Gullfaks C and its relation to Snorre A, and required Statoil to grant the researchers unlimited access to the key personnel.77

There were many early warning signals for the Gullfaks incident that were ignored by Statoil and its suppliers. For example, a kick that interrupted initial drilling shortly after the exploration was begun in December 2009 was wrongly categorized as a mild 3 level event rather than the more serious red 1 level and as a result was not investigated either by Statoil or the suppliers on the rig. At Gullfaks C the flow of information about safety and process integrity within the organization and the supply chains was obstructed in many ways. There were competing formal and informal safety systems and practices and no clear lines of authority or informal workarounds to resolve conflicts among them. As a result, there was no system in place capable of detecting the early signs of the dangerous situation or of reacting quickly as it unfolded.

The general difficulties of information management within Statoil were especially acute at Gullfaks C because of its history. Gullfaks was acquired by Statoil through its merger with Hydro, and the operating and safety systems on the rig consequently differed from those in in the new parent company. Moreover, there was staffing turbulence (layoffs, employees in new positions working with colleagues they did not know). Both local knowledge on the rig and informal experience based collaboration were undermined and important skills on the rig were lost.

The turbulence on Gullfaks C also disrupted communication and lines of authority between on and off shore actors. The disjoint distribution of information and authority left neither side in a position to diagnose and react to problems generated by drilling, and unable to cooperate to resolve problems jointly. Knowledge of operation was made increasingly person dependent. When workers rotated out of the rig for shift change or left because a shift to new suppliers, there was no clear procedure to transfer the knowledge that they had accumulated to their replacements. (The Iris report makes clear that his is a Statoil-wide problem: Offshore personnel routinely rotate out, taking their local knowledge and experience with them). Statoil addresses this issue, inadequately, by deploying expert consultants who have technical proficiency but no local knowledge of the rigs.

The merger also created additional procedural confusion and organizational opacity as Statoil’s documentation system (DocMap) was awkwardly integrated into Hydro’s documentation system (APOS). Simple procedures were made exceedingly complex. Actors on the rig ultimately ignored key procedures.

Organizational procedures further exacerbated these difficulties. Statoil relied on safety meetings with all relevant actors on the rigs to alert management to potential hazards. But the meetings documented decisions, not the concerns, warnings, doubts, or descriptions of circumstances that led to them. Additionally, disputes about jurisdiction and the allocation of responsibility led suppliers to ignore warnings from their own personnel and follow Statoil’s directives instead.

Managed Pressure Drilling (MPD), a demanding new technology, was also introduced on Gullfaks after the merger. The operators on the rig were unfamiliar with it and, as a result, failed to detect warning signs and generally ignored or underestimated risks. But even when they managed to communicate problems to higher management offshore, these communications were ignored.

Gullfaks C was under economic pressure to produce, and at low cost. The time allowed for planning the project and introducing the new technology was therefore abbreviated. One result was the failure to incorporate field experience into the planning process: planners were on shore, and the offshore personnel with field experience were not involved in the production planning.

Given all of these organizational problems, actors on the rig largely abandoned efforts to take precautions in advance of deploying the new MPD technology. For example, advanced pre-drilling analysis suggested that although the technique would work for the well, there could be difficulty removing the drill bits. But the rig crew, rather than think through an appropriate procedure, adopted a “wait and see” approach.

The failures at Gullfaks C and Snorre A were different in important ways—where Gullfaks C involved a compromised casing, the critical incident at Snorre A began with a botched effort to pull pipes out of the well, resulting in damage that led to an uncontrolled gas blowout on the seabed. But the root causes of both were similar: merger confusion, poor information flow due to staffing turbulence, little systematic planning, disregard of procedure, use of unqualified consultants, among others. This led to short-term, disconnected responses to problems as they emerged. Instead of intervening to correct these developments, key managers used their authority to induce less experienced colleagues to ignore or downplay irregularities and warning signs in the interest of rapid progress in drilling and cost reduction.

Both Statoil and the PSA carried out incident analyses after Snorre A. Generally, competence requirements were strengthened and risk assessment procedures at critical points at the well were instituted. A Subsurface Support Center was established to create cross-functional knowledge on the rigs. Directives were implemented to reduce paperwork complexity and redundancy. Non-essential tasks, unrelated to drilling operations, were transferred onshore, while managers offshore were focused on planning and resource issues relevant for the rig.
Despite these reforms, very little learning diffused in the industry. The Iris report suggests that in part this stems from Statoil’s reaction to the new directives (which came from PSA incident analyses). Statoil implemented each new suggestion to the letter, but made little effort to incorporate the new procedures into its own thinking about risk and production. As a result, there was formal compliance but no generative learning about risk management. At best, the new measures were window dressing for the PSA. At worst, they introduced greater confusion and organizational complexity into already complex organizations offshore. No one followed the rules by the letter because it took too long to get anything done. Moreover, there were many different systems of rules—the “discussion fora” established by the reforms had incompatible reporting and codification systems. At the same time, top managers on-shore worried so much about appearing to be in compliance that they overburdened offshore managers with bureaucratic paper work and distracted them from the turbulence of daily operations. As a result, little information was retained within the organization, at great cost to learning. Moreover, positive information was valued over warnings or critical observations.

The tripartite governance structure in the industry sometimes exacerbates this negative dynamic: employers, unions and PSA fight over the allocation of blame on basic crucial safety procedures, such as problem diagnosis, root cause analysis and the introduction of new technologies. Instead of a public good, information becomes proprietary. As a result, on a basic cultural level, there is little incentive to make information flow transparent or legible. The rule is, avoid writing things down, especially if they are controversial.

These same dynamics infect relations along the supply chain on the rigs. Statoil is known for its top down supplier relations. There are very detailed contracts that, formally at least, severely sanction deviation. Contracts are not only drafted but also apparently administered by on shore personnel. Statoil insists on compliance to contract language and procedure, but it does not monitor supplier behavior. PSA tracks supplier behavior and insists that suppliers construct “gap analyses” to indicate ways in which Statoil procedures and supplier procedures diverge on particular contracts. Suppliers must obtain a “coherence statement” (sammsvars uttalelse or SUT) from the PSA before signing a contract. SUT’s outline relevant parts of the supplier’s monitoring system, programs for maintenance and upgrading. But this arrangement does not work well in practice. Many contractors simply do not detail their procedures. Others say they will do whatever the PSA asks in order to obtain the SUT and then do whatever they want afterward, as there is no monitoring or auditing.

Statoil engages in little information exchange with suppliers ex post—there is no effort to capture and document the lessons learned through collaboration, or the possibilities for improvement. Yet supplier interest in these forms of cross platform, cross crew and supply chain exchanges is growing. Indeed, suppliers manage to learn amongst themselves generally and presumably also while working for Statoil,
even if the latter does little to encourage their efforts. Only 35% of Statoil-employees judge that they are good at learning from failures, while as many as 68% of those employed by suppliers judge that they do.\textsuperscript{78}

6. Signs of Renewal

Taken by themselves the Petoro analysis of declining efficiency and capacity to adopt innovation on the NCS, and the Iris investigation of the Gullfaks C incident depict an industry, and a regulatory authority, hamstrung by their own rules and procedures, able to observe yet not avert impending disaster. But that picture is partial and fundamentally misleading. The Norwegians—the PSA, the NOG and the firms operations on the NCS—are hardly supine, awaiting catastrophe. In response to more and more exacting evidence of dangerous shortcomings in key RNPP indicators, and the report on the Gullfaks C near miss and other reviews commissioned by oversight bodies, NOG, in concert (but not yet in close and explicit collaboration) with the PSA is developing the rudiments of a robust incident reporting system by which firms can, and perhaps will become obliged to, learn from each other to improve their safety management systems. Moreover, in response to the pressure for self scrutiny and re-organization induced by falling oil prices and declining efficiency, new consortia are developing on the NCS in which operators jointly hire a drilling rig, an operating company and an integrated supplier of services and, as successive wells are drilled, pool their experience in continuously improved protocols and procedures. Ideally these two forms of horizontal or peer-to-peer information exchange and learning would be mutually re-enforcing, with improved process control in safety critical areas contributing to improvements in efficiency and vice versa. There is some evidence that this complementarity is being realized in the new consortia.

But institutionalization of such mutually re-enforcing reforms industry wide, if it is possible at all, would likely require a re-interpretation of the idea of internal control that authorized extensive collaboration between the PSA and NOG to broaden and deepen the incident reporting system. Also necessary would be concomitant changes in the internal management of the operators, and increased willingness to share information about safety management systems and their performance that is now often regarded as proprietary. This part first presents the developments that together are creating the foundations of an incident reporting system, then describes the operation of the new consortia and reports some of their striking achievements in improved efficiency and high levels of safety. The next speculates briefly on the prospects of more comprehensive reform of the model of regulation and industrial organization on the NCS. For the sake of simplicity we omit

\textsuperscript{78} IRIS, p. 78.
discussion of information exchange fora, analogous to those of the NOG, but established by the Norwegian Shipowners Association, which represents mobile rig owners as well as cargo lines.

The projects on hydrocarbon leaks, the drilling managers forum, and the well integrity forum—all three, and especially the first and third, resulting from combined (but sometimes competing) efforts by the PSA and NOG—are creating new tools for reporting incidents, new conceptual schemes for categorizing and understanding their underlying causes, and new ways for regularly comparing routines and procedures among firms. All of these changes reach perforce into the management systems of companies operating on the NCS, at the least prompting re-examination of current practices. All of them also raise questions about the relation between the PSA and the NOG and the interpretation of the internal control doctrine. If horizontal exchanges among firms are becoming more and more important to the ability of individual firms to meet their internal control obligations, and NOG is largely responsible for organizing those exchanges, what is and should be the role of the PSA in the regulatory constellation?

The hydrocarbon leak projects. Hydrocarbon leaks are a major precursor of accidents in the off-shore oil and gas industry. They have been implicated in the catastrophes on the Piper Alpha and Deepwater Horizon platforms, and at the Longford and Texas City plants. Industry on the NCS started collecting data on the incidence of leaks of greater than .1kg/second—the flow rate above which dangerous accumulations can easily arise—beginning in 1996. The leakage rate was then increasing. It peaked, at 42/year in 2000, as the RNNP was beginning annual publication of the indicator.

The alarming trend led to two projects that ran in parallel from 2003 to 2008. The first, the GaLeRe (gas leak reduction) project, was organized by NOG and utilized accident reports to establish a rough classification of the causes of leaks, and to suggest preventive measures. In the second project the PSA also investigated the causes of leaks and traced the origins of many to actions by improperly trained personal. The upshot of the PSA project was the introduction of a series of courses on manual operations with flanges, fittings, valves and other equipment.\footnote{Vinnem, Jan-Erik, and Willy Ræed. "Norwegian Oil and Gas Industry Project to Reduce Hydrocarbon Leaks." \textit{SPE Economics & Management Preprint} (2014), p. 88.}

Although the number of leaks declined during the GaLeRe and PSA projects, reaching a low of 10 in 2007, the rate rose in the following years and NOG, in cooperation with major operators on the NCS, organized in 2011 a two-year, follow-on project to look more deeply into the root causes of leaks.\footnote{Roed, Willy, Jan Erik Vinnem, and Aud Nistov. "Causes and Contributing Factors to Hydrocarbon Leaks on Norwegian Offshore Installations." \textit{International Conference on Health Safety and Environment in Oil and Gas Exploration and Production}. Society of Petroleum Engineers, 2012.} The aim was to
develop countermeasures, not least by explicitly encouraging experience exchanges among firms on the NCS and between them and firms on the British continental shelf.

The study looked at the 62 relevant leaks on the NCS from 2008 to 2012, and was especially informed by analysis of the 33 for which the investigative reports supplied by companies were thorough and complete.\textsuperscript{81} The results confirmed the earlier finding that technical degradation of equipment is a secondary cause of accidents (accounting for 20 percent of leaks), as are design faults (11 percent), while manual interventions, which caused 60 percent of the leaks, are the dominant source of disruption. But close analysis showed that failures associated with manual interventions, and attributed in the earlier round of studies to failures in the “pointy end of the organization”—the front-line workers—were often caused by errors in preparing the intervention, particularly in planning and executing the plan to isolate the affected piece of equipment from the on-going process operations. In fact 59 percent of the leaks attributable to manual interventions originated in these upstream phases of the work: for example, when a faulty instruction was introduced into a work order because lessons from earlier experience were ignored or because the manufacture’s drawing did not accord with the equipment actually installed. In contrast, only 27 percent of the leaks were ultimately caused by errors introduced during the actual intervention on the targeted equipment.\textsuperscript{82} This shift in focus from the point at which the leak physically occurs to the location in the chain of institutionalized decision making at which, weeks or months earlier, the error(s) inducing the leak are introduced underscores the result, familiar from study of catastrophes such as the Deepwater Horizon and anticipated in the earlier discussion of the “technical” bias of the QRA,\textsuperscript{83} that accidents typically have long “event sequences” or “spirals to disaster.” They are best understood as the result of faulty routines, not as isolated procedural breakdowns.\textsuperscript{84} The result is that the distinction between “normal” and “safety critical” work is effaced.\textsuperscript{85} This connection between systematic failures in organization and heightened risk was indirectly

\textsuperscript{85} ibid.
confirmed by the finding that the divergence between the best and worst companies with respect to leaks has increased in recent years.\textsuperscript{86}

The immediate outcome of the project has been the reduction of leak rates to unprecedentedly low levels, though it is of course impossible to determine just how much project interventions contributed to this result or how enduring it will be.\textsuperscript{87} The project has however also touched off a cascade of institutional reactions that are almost certainly to be of long-term significance. Several companies have compared their best practices for maintenance and the NOG has, together with a working group including representatives of all the major firms operating on the NCS, codified the project’s synthesis of these in a common best-practice guideline. The PSA refers to this and other guidance originating in the project, giving it official weight. To address the inconsistencies and incompleteness of accident reports, the project developed and introduced a standard questionnaire, which directs attention to the incidence of errors in the various phases of the work process.\textsuperscript{88} Imperfect as it is, the data assembled by the project is sufficiently fine grained to show that remedial measures taken by Statoil in response to the first round of projects are thus far ineffective, prompting further reform.\textsuperscript{89}

In short, the hydrocarbon leak project has introduced initiatives that have reduced risk levels, at least temporarily. It sets the stage for further and enduring reductions through improved reporting and more precise categories of analysis; and wretches up already heightened pressure on the laggards to adopt their version of the best practices in place at leading firms. The PSA is hardly oblivious to these developments. Beyond referring to the pertinent NOG guidelines, the RNNP trends summary for 2013 observes without commentary that

the four facilities with the highest average frequency [of hydrocarbon leaks] during the period 2009-2013 – all with the same operating company – together account for more than 25% of the number of leaks on the NCS during this period. Two of the five facilities with the highest average frequency have been among the top five in equivalent overviews in RNNP reports since 2005.\textsuperscript{90}


\textsuperscript{87} ibid


**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, fora for the industry-wide discussion, analysis and response to well control incidents such as the sudden influx of formation fluids into the wellbore—a “kick.” Eventually specialized groups were formed to track and deepen understanding of problems emerging in each stage of the life-cycle of a well, 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 a collection of ad hoc initiatives, and they are depicted in NOGs own presentations as the nucleus or foundation of a comprehensive structure.

The first and still central component of this emerging structure is the Drilling Managers Forum (DMF). The DMF was established in 2002 under the leadership of Jan Krokeide, a consultant and part-time employee of NOG, widely respected in the industry as a successful manager of Odfjell, an integrated drilling contractor. Krokeide emphasized from the outset that differences in company cultures and requirements created safety risks that were best addressed by developing shared understanding of problems and responses. Drilling managers for 13 operating companies participated at the start. The DMF’s mandate is broad: In addition to promoting HSE excellence through continuous improvement on the NCS, it is to keep abreast of operational and technological developments; foster the exchange of experience and learning; comment on proposed regulations; and assist in organizing and staffing further projects. It is through this authorization to create further, more specialized fora that the DMF has generated and become the stabilizing center for the emergent system of well life-cycle incident reporting.

Two groups are key: the Well Incident Task Force (WITF) and the Well Integrity Forum (WIF). The WITF convenes managers from operators and drilling contracts to recommend ways to reduce the frequency and potential severity of well control events on the NCS. It does this by analyzing recent well control incidents at monthly meetings; the cases (10 so far) are then elaborated and posted on the web under the rubric of “sharing to be better.” The presentations are extremely detailed, typically including logs showing the readouts of instrumentation at critical moments during the incident, and pedagogically structured: Questions like “would you have reached this conclusion?” or “when was the last time this instrument was calibrated on your rig?” punctuate the narrative of events. The incidents invariably call

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91 Offshore.no, Boresjefør engasjert i sikkerhetsarbeid
December 2, 2002.
93 the cases are located here: http://www.norskoljeoggass.no/en/Activities/HSE-and-operation/Major-accident-risk/Well-control-incidents1/
attention to the interplay between organizational factors—the data operator on a platform asks a geologist on shore to provide a parameter for a calculation; the geologist is distracted and tells the operator to consult a table of values; the operator chooses the wrong value; his supervisor does not perform the required check of the calculation and three levels of drilling managers (Drilling Supervisor/Toolpusher/Driller) fail to notice the resulting, abnormal increase in drill speed.\textsuperscript{94} 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. As noted above, the establishment of this forum was prompted by the PSA study in 2006 showing that nearly 20 percent of production wells are impaired. The WIF focuses accordingly on the operating stage of the life cycle, after wells have been handed over from the well drilling unit to production managers. Informed by discussion of recent incidents it produces guidelines on training, handover documentation and standardized barrier drawings, and comments as well on regulatory proposals.\textsuperscript{95}

In addition the WIF has developed the traffic-light categorization of well robustness described earlier. Use of this tool is still limited because the categories capture only the condition of the well structures, but do not classify the surrounding conditions, such as features of the formation. Without reference to this additional information it is impossible to estimate the consequences of structural failure, and therefore impossible to use the existing tool to prioritize efforts at mitigation. Efforts are underway to devise a more robust system of classification that gauges risk levels by considering both the probably of failure and the severity of its effects.\textsuperscript{96}

Figure 1 shows NOGs view of the system that has developed out of and remains centered on the DMF, including a reference to a third forum on plugging and abandonment, at the end of the well’s life cycle. In recent announcements, of hearings on revised standards, for example, the PSA refers to the same constellation.\textsuperscript{97}

\begin{footnotesize}
\textsuperscript{94} Offshore Semi Sub Rig, Well Control Incident, Sharing to be Better, Case 2, at http://www.norskoljeoggass.no/Global/Sharing%20to%20be%20better/Sharing%20to%20be%20better%20Case\%202.pdf


\textsuperscript{97} See PSA, Draft version of revision 4. of NORSOK D-010 Well Integrity in Drilling and Well Operations is ready for enquiry, January 4, 2013: “The oil & gas industry in general, and members of Norwegian Oil and Gas Association (including work groups like DMF, PAF, WIF) and the Norwegian Petroleum Safety Authority (PSA) in particular, are invited to provide suggestions for improvements no later than 2013-02-15,” at http://www.psa.no/news/revision-4-of-d-010-is-ready-for-enquiry-article9031-878.html.
\end{footnotesize}
6.3 Three Limits to this Initiative: Participation, Diffusion and Enforcement

The development of these groups and fora is hampered by the fact that engagement at every stage in their activity is voluntary. NOG is a trade association. Because it has the trust of the member firms it represents it has substantial convening power. But as the members’ representative, it cannot compel them to actions beyond those they have authorized or willingly tolerate. This tension is inherent in the nature of trade associations. The problems to which it gives rise are general and familiar, even if their ultimate resolution depends on the particulars.

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of the industry and national, or international context. For now in the Norwegian oil and gas industry the tension is manifest in three ways.

The first regards the breadth and depth of participation. Individual managers willingly engage with each other as professionals. Working together to understand and solve problems is what they do. But companies are often hesitant to share information about incidents that may cast them in an unfavorable light, or reveal details of management systems they regard as proprietary. So not all companies allow their managers to participate in the fora, and even those that do may not clarify until the last possible moment just how much information they are willing to make public through a posting of an incident discussion to Sharing to be Better.

The second regards the use of protocols for collecting and analyzing incident information, and diffusing the results of analysis. Companies are not formally obligated to employ, for example, the new questionnaire on hydrocarbon leaks, nor to pursue the work-phase investigation of root causes the questionnaire prompts; nor are they compelled to respond to incident reports, for example by explicitly determining whether the lessons learned might be relevant to their own operations. The “sharing to be better” presentation of cases invites such self-reflection, but stops there. Firms are left to their own devices to absorb or not the lessons learned.

Indeed, compared to the most sophisticated company-based incident reporting systems, such as Shell Oil’s Learning from Incidents (LFI) process, the constellation forming under NOG auspices looks haphazard—a patchwork. LFI, for example, complements its classification system for the severity of incidents 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. It emphasizes “causal investigation” aimed to organizational levels that ultimately “cause” the problem: 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 is also and more fundamentally a problem in the organization of the design process, which failed to detect the original misspecification. Finally, by way of diffusion, LFI analysis doesn’t produce traditional reports. Rather the output of analysis is a document presenting contributing circumstances. It is used to structure meetings in which the relevant groups in facilities that could be implicated in similar incidents, including front-line workers, reflect on how they might have contributed to related problems—and what to do to avoid such contributions: The “observations inside conclusions” (OICs) produced by these groups often improve on solutions devised by the original incident investigation team.

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100 Interview
But the differences between current DMF system and company best practice 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 essentially all of the cogent aspects of systems such as LFI, including a section on “alternative” forms of learning that dovetails with the innovative and participatory features of OICs. 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 how much of what they know can be implemented.

This question leads naturally to the third tension in the conflicted role of the trade association as representative of industry firms and potential co-regulator, along with the PSA, of those firms’ behavior: enforcement. In principle the PSA can give de facto legal effect to NOG guidelines simply by indicating in its own guidance that behavior in conformity with the guidelines presumptively meets various regulatory requirements. There are cases, particularly in connection with the hydrocarbon leaks projects, where this is already the case. As of now both parties, NOG and the PSA, are leery of making much of this possibility. NOG is hesitant because it does not want to antagonize the PSA by seeming to usurp its prerogatives, nor to antagonize its members by acting beyond their mandate and contributing to the imposition of unwanted obligations. The PSA is hesitant because while the formation of an integrated incident reporting system could be interpreted as a development of firms’ existing obligation to maintain an effective safety management system, it could also be interpreted as an impermissible violation of the internal control principle. Of course the resolution of this tension depends in large measure on how the firms internal organization and forms of collaboration develop, and we return to this complex of questions below.

6.b New forms of firm organization and contracting

Much of the adjustment to collaboration in the increasingly vertically dis-integrated economy on the NCS is informal and therefore almost invisible. A supplier of a complex service, such as laying underwater pipe, enters a traditional contract with a customer assigning the supplier responsibility for solving problems and the risk of failing to do so. In practice the customer co-locates a number of engineers in the suppliers’ design offices for months at a time to jointly plan the operation. If problems arise that can’t be solved during weekly reviews, the lawyer managing the contract for the supplier knows senior managers on both sides will want to know of the deadlock and will try to get their subordinates to find a resolution before

stepping in themselves. Or, in confidential contract discussions, a large, integrated service supplier will suggest that when problems arise buyer and seller establish a joint team to undertake root cause analysis rather than try to assign responsibility for effort through interpretation of contract language. Thus even if the contract provisionally remains the same, the parties may begin to act differently.

More formally, but still hard to observe at any distance, is the creation of some 60 new firms on the NCS. Operating in different segments of the industry, these firms are often populated by managers from established companies (especially from Statoil). It is hard to assess the impact of these new entrants; but key managers are plainly responding to rigidities in the incumbent producers. Their willingness to take substantial personal risks to realize the potential of plans that could not be put into action within the existing structures recalls the behavior of managers of who left US Steel and other integrated producers in the US in the 1970s and 80s to establish what is today the highly competitive mini mill segment of the industry. 102

But the most conspicuous example of organizational adjustment is the emergence on the NCS of a new type of drilling consortium that increases efficiency—to well above the area average—while reducing risk through rapid, collaborative learning. The key innovation is systematic collaboration—between members of the consortium, between onshore and offshore personal, between drilling contractor, operator managers and service provider on the rig—that allows for rapid revision of plans in light of problems encountered in their execution, and the capture and subsequent application of lessons learned in each step in the drilling campaign.

Traditionally on the NCS consortia were makeshifts. Large operators, with internal drilling departments and long-term drilling plans, hired drilling rigs for years at a time for their sole use, subletting if necessary. Smaller operators, none big enough to hire a rig alone, formed consortia, in which the largest among them hired a rig contractor and service providers under terms that were then accepted by the others. This arrangement solved the problem of rig access for smaller firms, but largely precluded efforts to learn from on-going operations as the terms of cooperation were fixed in advance and there were no routines for adjusting them.

Starting in the late 2000s, as rig contract prices climbed and efficiency concerns for this and other reasons became paramount, smaller operators sought more control over the conditions under which their wells were drilled. The result was the creation of collaborative consortia, in which the operators cooperate in establishing framework conditions with the rig contractor, a well drilling company (in effect the general contractor for the whole project) and the supplier. This initial cooperation sets the stage for closer cooperation among the actors drilling each well and for the handoff of the accumulated knowledge to successive operators.

102 See Herrigel, Manufacturing Possibilities, ch 3, pp 100-138
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 this new arrangement. The lead operator was the BG Group, a British multinational. Consortium operators and the rig contractor, Seadrill, established general conditions of "safe efficiency" in workshops and regular meetings before the rig began the drilling campaign. The consortium operators’ steering committee resolved to hire 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 continuity of key personnel through the whole campaign and to allow counterparts on the rig to focus on urgent operational issues. A number of new positions were created to ensure close and continuing coordination between planning and operational units at every phase of well drilling: An "on-shore toolpusher" was, for example, posted from the rig to the on-shore planning group, so that the current operator was fully abreast of conditions on the rig and that drilling programs could be optimized in view of a fully informed understanding of rig capacities. On the platform, a rig contractor “optimizer” was embedded in the operator’s rig team, again to improve operational planning and execution, for instance, by planning each section of the well bore. A “master action register,” continuously updated, was used to capture lessons learned and to pass them on to successive operators. WAC set numerous records—fastest exploration well in Norway, 2470 meters in 9.8 days—and operated for more than a thousand days without a single lost time incident.\textsuperscript{103} Petoro, whose careful study of increasingly inefficiency on the NCS we examined earlier, presents the WAC as “a benchmark for efficient drilling.”\textsuperscript{104}

Another prominent and successful consortium developing this model leased the Bredford Dolphin semisubmersible rig for 3 years starting in 2006. Five operators again participated, including, as in the WAC, the BG Group and Det norske Oljeselskap (DNO), widely seen as one of the most innovative firms on the NCS. The well management company or general contractor was AGR Petroleum Services; Haliburton was the integrated service supplier. As in the WAC, the operators, service provider, and rig owners optimized their internal planning processes while contributing to the pooled expertise of the consortium. The same was true of HSE. Each operator had its own routines; the well management company, in consultation with the other actors, selected among these to form a composite and consistent best practice; a safety coach oversaw regular verification of the application of best practice on the job. Planning of drilling operations involved joint assessment of risks by the key actors at every stage. Daily drilling operations were under the control of the well management company, but there were weekly meetings between the


management company and the current operating company, and representatives of the operators also participated in the daily morning rig meetings. The results were again notable: a benchmarking exercise showed that the costs of drilling eight out of the ten wells undertaken by DNO were below the industry average—50 percent of DNO’s wells were in the lowest quartile of costs for comparable wells in the industry; and costs decreased as successive wells were drilled while the meters drilled by day increased, demonstrating significant learning effects. DNO in any case is well satisfied with the results: Earlier this year it entered a 3-year, framework agreement with the AGR group to manage well campaigns, with the possibility of extending the collaboration through 2021.

7. Stalemate or Regeneration? An Invitation to a Discussion

[This is the place for a conclusion and it is intentionally left blank, or almost. We think we can fairly conclude that developments in Norway, seen against the broader backdrop of changes in regulation to which we refer, strongly suggest that there is pressure on firms to collaborate much more closely with one another in joint production, and with the regulator in capturing, evaluating and responding to incidents or signs of emergent risk. But this is an inconclusive conclusion, as least for Norway, the focus of this essay, and by extension for any national industry and regulator that sense the direction of developments but wonder, how can and should we respond? It is easy to imagine the situation described in the preceding sections ending in stalemate, with the incremental change in progress and documented here blocked—at least until economic pressure forces action under strained and risky circumstances. But it is also possible to imagine that the changes in the organization of production and regulation coalescing into a new regime that is

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both more efficient and less catastrophe prone. Call it NORSOK 2.0.

We think that you, our discussion partners and the first readers of this draft, are in a better position to reflect on both possibilities than we are. In any case it would be folly for us to advance ideas on these lines without consulting closely with you.

The usual way of doing this is to commit something to paper and solicit your reactions. In this case we think that we should reverse the process: It will be better for all if we build on your own thoughts and reactions to our argument so far than if you respond to our speculative errors. Below, therefore, are the barest of bare-bones topic headings for discussion of these themes to prompt engagement. Our hope is to organize a seminar this winter or early in the spring to discuss your thoughts. As ever, we are extremely grateful for your help.]

Stalemate?

Fights or even anxieties over jurisdiction between NOG and the PSA lead to blockage in regulatory reform; Statoil remains dominant, but inefficient. The upshot is increasing cost pressure and increasing risk--resulting, perhaps, in a desperate lunge for a solution made all the more risky by delay and the frustration of hidden conflict.

Renewal?

The PSA revises its understanding of the self 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.

Statoil embraces continuous improvement/incident reporting regimes that reduce risk and allow for efficiency enhancing collaboration.

The success of the new consortia and the lead firms in them prompt a revision of the contract regime to encourage collaboration and information sharing among operators, where relevant, and between operators and suppliers.

Unions find a new or a additional role as pillars of the incident reporting regime, giving renewed meaning to the Nordic or Norwegian model of regulation.