Föreläsning 12 (Sista)

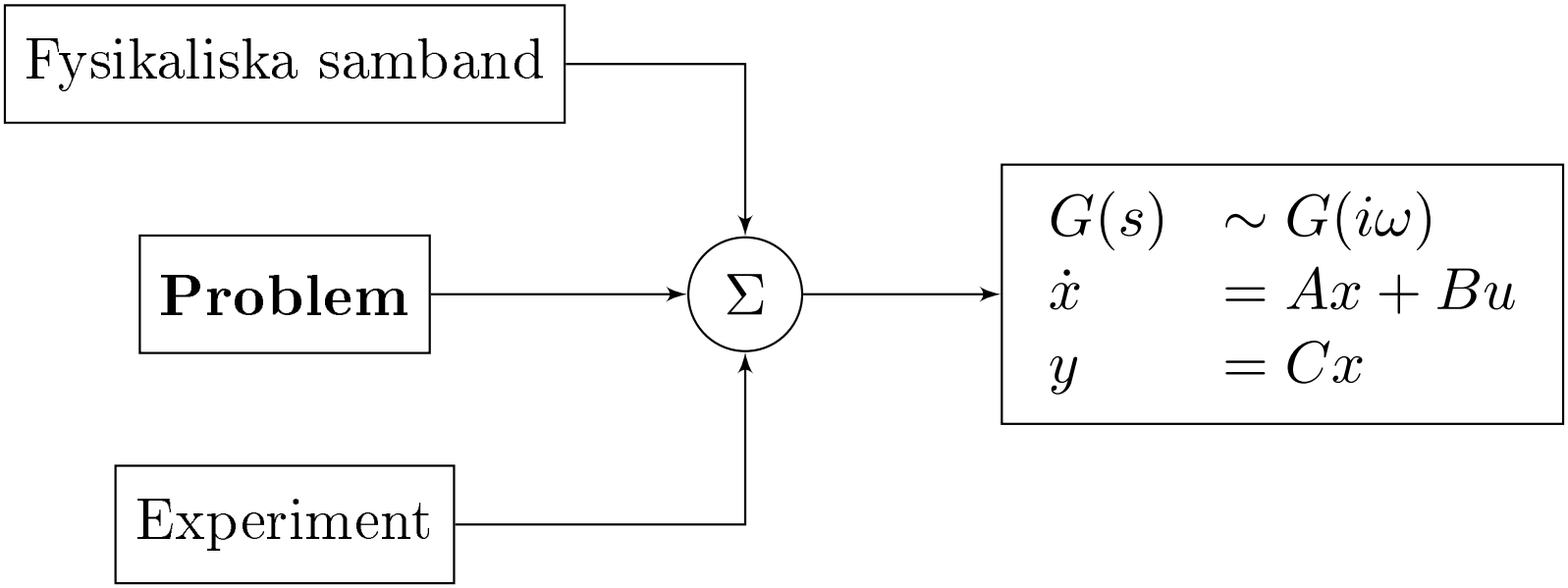
Reglerteknik AK

©Bo Wahlberg

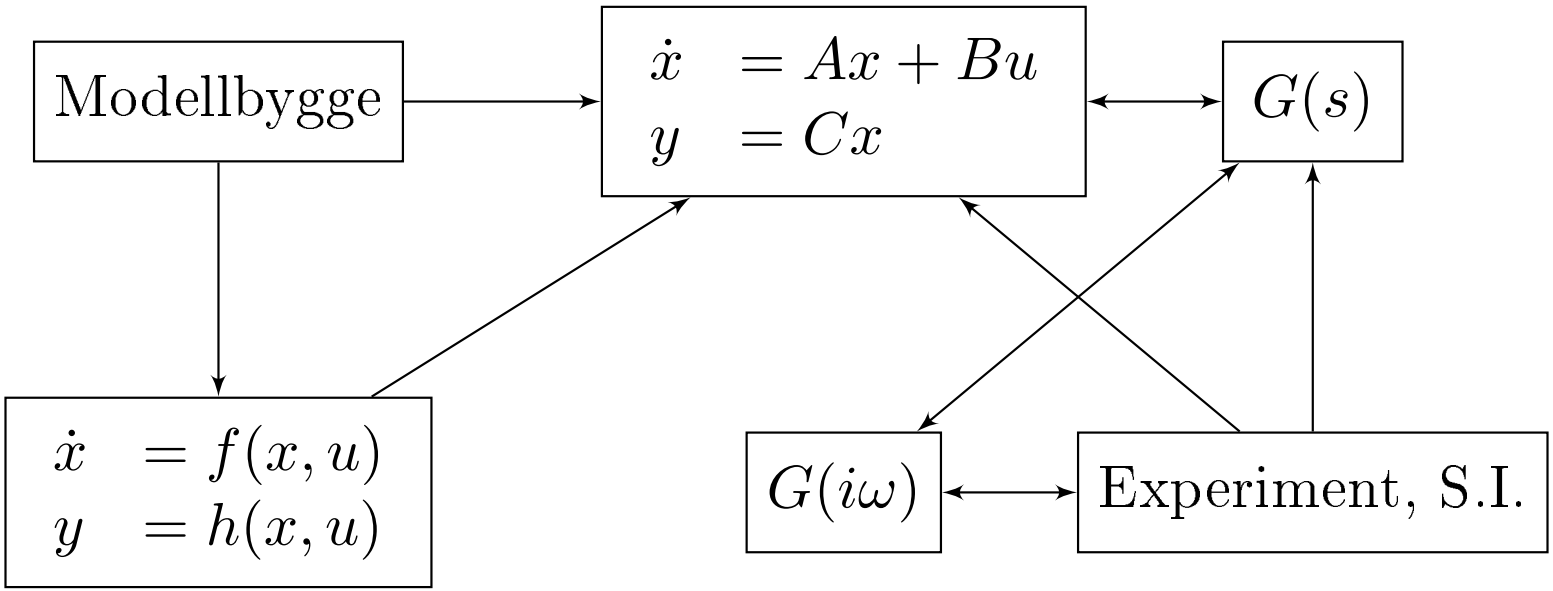
Avdelningen för reglerteknik
Skolan för elektro- och systemteknik

7 Oktober 2014

Sammanfattning



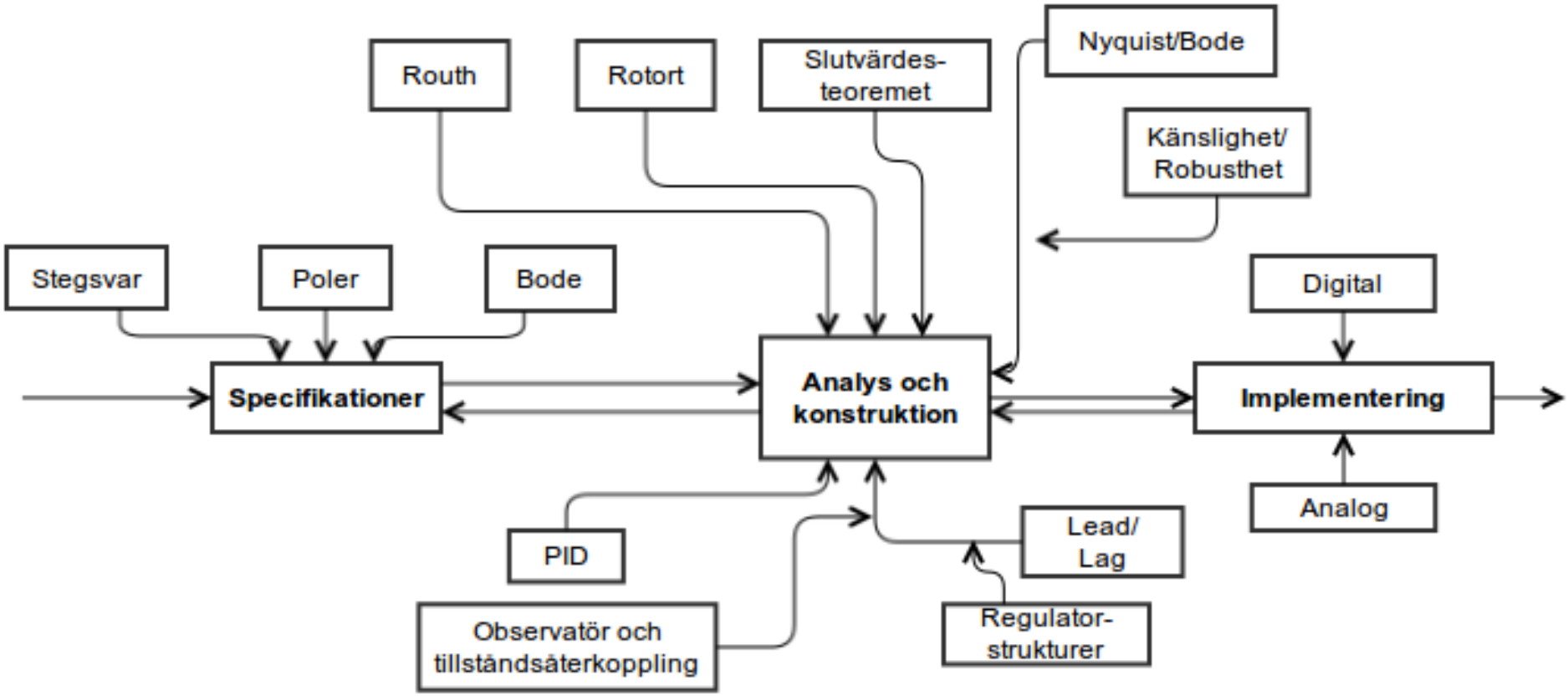
Sammanfattning



Verkliga system är komplicerade:

$$G^0(s) = G(s)\big[1 + \Delta_G(s)\big], \quad |\Delta_G(i\omega)| \leq g(\omega) \ \ \forall \ \ \omega$$

Sammanfattning



Sammanfattning - Rotort

Rotort:

I. n Startpunkter $(K = 0)$

II. m Ändpunkter $(K = \infty)$

III. Var ligger ∞? (Asymptoter)
Riktning: $\frac{\pi}{n-m} + k \cdot \frac{2\pi}{n-m}$
Skärningspunkt: $\frac{1}{n-m}\left(\sum p_i - \sum q_j\right)$

IV. Skärning med reella axeln. "*Udda summa*"

V. Skärning med imaginära axeln. Ansätt $s = i\omega$

VI. Rita rotort och **dra slutsats**

Sammanfattning - Slutvärdesteoremet

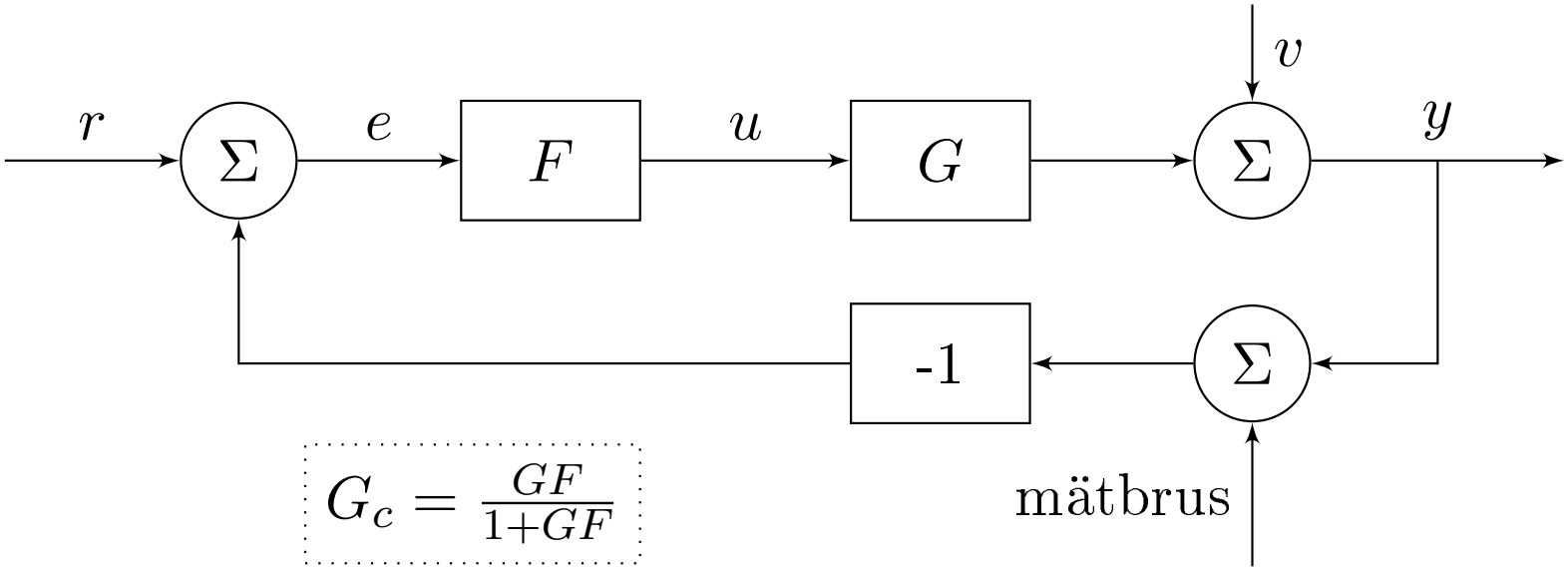
Slutvärdesteoremet:

Kom ihåg att kolla att slutvärdet existerar! (slutna systemets poler strikt i V.H.P.)

Steg $\frac{1}{s}$

Ramp $\frac{1}{s^2}$

Sammanfattning - Specifikationer



Tidsdomänen:

Stigtid: T_r

Insvängningstid: T_s

Översläng: M

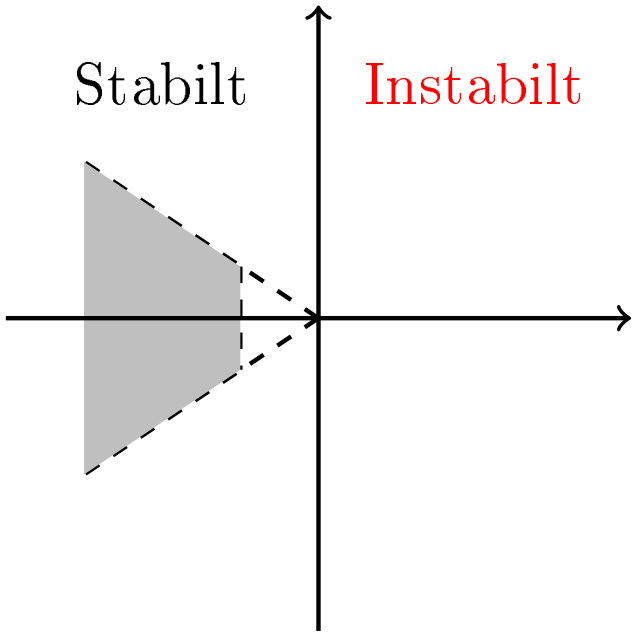
Frekvensdomänen:

Bandbredd: ω_B

Resonanstopp: M_p

Resonansfrekvens: ω_r

Sammanfattning - Poler



Avstånd till origo $\approx$ snabbhet
Vinkel $\approx$ svängighet

Sammanfattning - Poler

Nyquist:	**Bode:**
$G_o(i\omega)$	$\lvert G_o(i\omega)\rvert,\ \arg\left[G_o(i\omega)\right]$

Tolkning $\leftrightarrow$ rita

$$\left.\begin{array}{ll} \text{skärfrekvens:} & \omega_c \\ \text{fasmarginal:} & \varphi_m \end{array}\right\} \quad \leftrightsquigarrow \quad |G(i\omega_c)| = 1$$

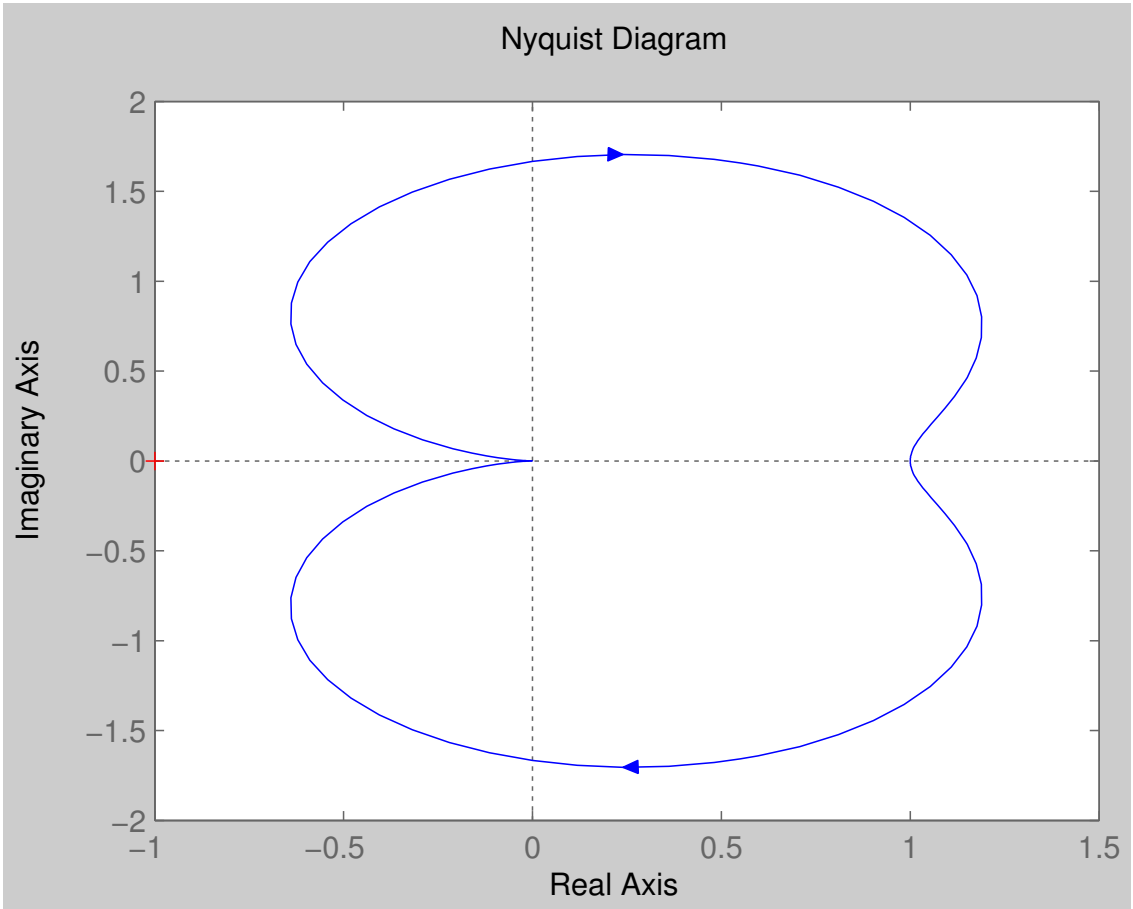
Amplitudmarginalen kan läsas av i Bodediagram eller Nyquistkurva (se figur 5.2 samt 5.3 i boken).

Sammanfattning - Nyquistkriteriet

Antag att $G_o(s)$ saknar poler i H.H.P. och att Nyquistkurvan **ej** omcirklar -1.

$\Rightarrow$ $G_c(s)$ saknar poler i H.H.P.

$\Rightarrow$ Stabilt återkopplat system.



Sammanfattning - Bodediagram

Öppna systemets Bodediagram $\leftrightarrow$ Slutna systemets Bodediagram

Fördubbla $\omega_c \nleftrightarrow$ Fördubbla ω_B

$\varphi_m \sim M_p$

liten $\rightarrow$ *stor* $(\varphi_m \approx 50^\circ - 60^\circ$ OK)

$G_o(i\omega)$ stor $\Rightarrow G_c(i\omega) \approx 1$

$G_o(i\omega) \approx -1 \Rightarrow G_c(i\omega)$ stor

Sammanfattning - Känslighet och störningar

Känslighet (störningar):

$$S = \frac{1}{1 + FG}$$

Robusthet (modellfel):

$$T = \frac{FG}{1 + FG} = 1 - S$$

Sammanfattning - Konstruktion

PID-regulator:

$$U(s) = K\left(1 + \frac{1}{T_I}\frac{1}{s} + T_D s\right) = K_P + K_I\frac{1}{s} + K_D s$$

Lead-/Lag-länk:

$$F(s) = K\frac{\tau_D s + 1}{\beta\tau_D s + 1}\frac{\tau_I s + 1}{\tau_I s + \gamma}$$

Önska $\bar{\omega}_c$ (Lägg till 5.7° extra på fasmarginalen, φ_m)
$\Longrightarrow \beta \Longrightarrow \tau_D \Longrightarrow K$

$\tau_I = \frac{10}{\bar{\omega}_c}$ (iterera)

Välj γ liten.

Sammanfattning - Tillståndsteori

$$\begin{cases} \dot{x} &= Ax + Bu \\ y &= Cx \end{cases}$$

$$\boxed{\begin{array}{c} \dot{\hat{x}} = A\hat{x} + Bu + K(y - C\hat{x}) \\ \det\left[sI - (A - KC)\right] = 0 \end{array}}$$

$$\boxed{\begin{array}{c} u = -Lx + l_0 r \\ \det\left[sI - (A - BL)\right] = 0 \end{array}}$$

$$\Downarrow$$

$$\boxed{u = -L\hat{x} + l_0 r}$$

Styrbarhet + Observerbarhet

Sammanfattning

Regulatorstrukturer:

- Framkoppling
- Kaskadreglering
- Otto Smith

Implementering:

- Euler bakåt
- Tustins formuel

Differentialekvationer $\mapsto$ differensekvationer

Tentan

- Man får ha boken och Beta med sig (samt. miniräknare).
  Läs boken innan tentan!
- Problemlösning (ej utantillavskrivningar). Träna på gamla tentor!
- **Observera** att man måste vara anmäld för att få skriva tentan!

Mer kurser

Master's programme in Systems, Control and Robotics!

- Olinjär reglering, period 2
- Hybrida och inbyggda reglersystem, period 3
- Reglerteknik, fortsättningskurs , period 4
- Modellering av dynamiska system, period 1

Your Future

Disruptive technologies: Advances that will transform life, business, and the global economy

According to McKinsey Global Institute (Maj 2103):

Speed, scope, and economic value at stake of 12 potentially economically disruptive technologies

	Illustrative rates of technology improvement and diffusion	Illustrative groups, products, and resources that could be impacted[1]	Illustrative pools of economic value that could be impacted[1]
 **Mobile Internet**	**$5 million vs. $400**[2] Price of the fastest supercomputer in 1975 vs. that of an iPhone 4 today, equal in performance (MFLOPS) **6x** Growth in sales of smartphones and tablets since launch of iPhone in 2007	**4.3 billion** People remaining to be connected to the Internet, potentially through mobile Internet **1 billion** Transaction and interaction workers, nearly 40% of global workforce	**$1.7 trillion** GDP related to the Internet **$25 trillion** Interaction and transaction worker employment costs, 70% of global employment costs
 **Automation of knowledge work**	**100x** Increase in computing power from IBM's Deep Blue (chess champion in 1997) to Watson (Jeopardy winner in 2011) **400+ million** Increase in number of users of intelligent digital assistants like Siri and Google Now in past 5 years	**230+ million** Knowledge workers, 9% of global workforce **1.1 billion** Smartphone users, with potential to use automated digital assistance apps	**$9+ trillion** Knowledge worker employment costs, 27% of global employment costs
 **The Internet of Things**	**300%** Increase in connected machine-to-machine devices over past 5 years **80–90%** Price decline in MEMS (microelectromechanical systems) sensors in past 5 years	**1 trillion** Things that could be connected to the Internet across industries such as manufacturing, health care, and mining **100 million** Global machine to machine (M2M) device connections across sectors like transportation, security, health care, and utilities	**$36 trillion** Operating costs of key affected industries (manufacturing, health care, and mining)
 **Cloud technology**	**18 months** Time to double server performance per dollar **3x** Monthly cost of owning a server vs. renting in the cloud	**2 billion** Global users of cloud-based email services like Gmail, Yahoo, and Hotmail **80%** North American institutions hosting or planning to host critical applications on the cloud	**$1.7 trillion** GDP related to the Internet **$3 trillion** Enterprise IT spend
 **Advanced robotics**	**75–85%** Lower price for Baxter[3] than a typical industrial robot **170%** Growth in sales of industrial robots, 2009–11	**320 million** Manufacturing workers, 12% of global workforce **250 million** Annual major surgeries	**$6 trillion** Manufacturing worker employment costs, 19% of global employment costs **$2–3 trillion** Cost of major surgeries
 **Autonomous and near-autonomous vehicles**	**7** Miles driven by top-performing driverless car in 2004 DARPA Grand Challenge along a 150-mile route **1,540** Miles cumulatively driven by cars competing in 2005 Grand Challenge **300,000+** Miles driven by Google's autonomous cars with only 1 accident (which was human-caused)	**1 billion** Cars and trucks globally **450,000** Civilian, military, and general aviation aircraft in the world	**$4 trillion** Automobile industry revenue **$155 billion** Revenue from sales of civilian, military, and general aviation aircraft

	**Next-generation genomics**	**10 months** Time to double sequencing speed per dollar **100x** Increase in acreage of genetically modified crops, 1996–2012	**26 million** Annual deaths from cancer, cardiovascular disease, or type 2 diabetes **2.5 billion** People employed in agriculture	**$6.5 trillion** Global health-care costs **$1.1 trillion** Global value of wheat, rice, maize, soy, and barley
	**Energy storage**	**40%** Price decline for a lithium-ion battery pack in an electric vehicle since 2009	**1 billion** Cars and trucks globally **1.2 billion** People without access to electricity	**$2.5 trillion** Revenue from global consumption of gasoline and diesel **$100 billion** Estimated value of electricity for households currently without access
	**3D printing**	**90%** Lower price for a home 3D printer vs. 4 years ago **4x** Increase in additive manufacturing revenue in past 10 years	**320 million** Manufacturing workers, 12% of global workforce **8 billion** Annual number of toys manufactured globally	**$11 trillion** Global manufacturing GDP **$85 billion** Revenue from global toy sales
	**Advanced materials**	**$1,000 vs. $50** Difference in price of 1 gram of nanotubes over 10 years **115x** Strength-to-weight ratio of carbon nanotubes vs. steel	**7.6 million tons** Annual global silicon consumption **45,000 metric tons** Annual global carbon fiber consumption	**$1.2 trillion** Revenue from global semiconductor sales **$4 billion** Revenue from global carbon fiber sales
	**Advanced oil and gas exploration and recovery**	**3x** Increase in efficiency of US gas wells, 2007–11 **2x** Increase in efficiency of US oil wells, 2007–11	**22 billion** Barrels of oil equivalent in natural gas produced globally **30 billion** Barrels of crude oil produced globally	**$800 billion** Revenue from global sales of natural gas **$3.4 trillion** Revenue from global sales of crude oil
	**Renewable energy**	**85%** Lower price for a solar photovoltaic cell per watt since 2000 **19x** Growth in solar photovoltaic and wind generation capacity since 2000	**21,000 TWh** Annual global electricity consumption **13 billion tons** Annual CO_2 emissions from electricity generation, more than from all cars, trucks, and planes	**$3.5 trillion** Value of global electricity consumption **$80 billion** Value of global carbon market transactions

1 Not comprehensive; indicative groups, products, and resources only.
2 For CDC-7600, considered the world's fastest computer from 1969 to 1975; equivalent to $32 million in 2013 at an average inflation rate of 4.3% per year since launch in 1969.
3 Baxter is a general-purpose basic manufacturing robot developed by startup Rethink Robotics.

SOURCE: McKinsey Global Institute analysis