

 **DTU Compute**  
Department of Applied Mathematics and Computer Science

# Generation of Business Process Models for Benchmarking Purposes

A metrics-based approach

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# Abstract

[ - ^%s%z\ s eCqHb\ z- sW zP- z q\ ~Sf eqp<Css \ b@C\ - s S'e~zi Gbq zCzS'L zPC eCqHb\ - ^<C bHZPCs s%z\ s> S S ~sCHYzb eqfS@C - 4C^<P\ - qW<b^sSzS'L bH- <bYC-zb^ bHeq<Css \ b@Csi Ob..CfCq<b^szq<zS'L - <bYC-zb^ ..SP <Cq- S' @CsSf@ <P- q <CfzSs Hb\ qC YHC \ b@C\ <- ^ 4C @S <- Y - ^@zS C <b^s~\ S'Li 3%~zbQ \ - zS- Y%LC^Cq zS'L zPC <bYC-zb^> S <- ^ 4C <b^szq<zC@HszCq- ^@..SP \ bqC G sC> 4-z zPS e~zs PSLP @C - ^@s b^ zPCLC^Cq zS^ - YbqfP\ eqfS@S'L <b^zpbYbHZPC<P- q@ - <CfzSs bHZPCLC^Cq zC@<bYC-zb^i B+SzS'L - YbqfP\ s CSfCqeqfS@C YzC@SfCz <b^zpbYbfCq zPGC <P- q <CfzSs> bq q\ ~SfC- s\ - YCq <bYC-zb^ bH\ b@C\ ..SP zPC s\ C <P- q <CfzSs zb 4C- f- SY 4Y yPS ..bqWeqebSs - eqp<Css \ b@CYLC^Cq zbq zP- z z- Ws zPC @CsSf@ <P- q <CfzSs - s S'e~z S' zPC Hb\ bHeq<Css \ b@CY Czfz> eqfS@S'L @SfCz <b^zpbYbHZPC <P- q <CfzSs bHZPCLC^Cq zC@<bYC-zb^i yPC \ - S' S@G bHZPC- YbqfP\ S zb LC^Cq zC G <P \ b@CY4%S<qC C^z- Y%qC@-S'L zPC @S Cq C^<C 4z..CC Ss <- qC^z - ^@ @CsSf@ <P- q <CfzSs> ~^zSY- s zSH<zbq%sbY-zb^ S \ Czi yPS - eeq<P eqp@<Cs <bYC-zb^s ..SP <P- q <CfzSs zP- z YqC%qCs\ 4C zPC @CsSf@ b^Csi ,, PSC S @bCs P- fC <Cq- S' sPbz<b> S'LS>s~<P- s eqfS@S'L <b\ eqC PC^sSfCs-eebz Hbq b^Y% s\ - YsCz bH Czfz>..PSP \ - Ws S S eq <zS- YHbq~sCS' qC YHC sS~ - zb^s>S eqebSs ebssSYCsbY-zb^s Hbq <P bHZPCs>- ^@S - sL^S <- ^z "qz szCe zb..: q@s @CSL^S'L - eq <zS- Y- YbqfP\ i



# Preface

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yPS\$ zPCs\$ ...s eqCe- q@-z zPC@Ce- qz\ C^z bH, eeY@| -zPC\ -zSs -^@; b\ e~zCq  
r<S^<C -z zPC yC^P^S- Y} ^S/CpS%bH? C^\ -qWS^ HY Y C^z bHzPC qd ~Sq\ C^zs  
Hbq -d ~Sq^L - [ -szCq bHr<S^<C S^ B^LS^CCq^L @LqCC S^ ; b\ e~zCq r<S^<C -^@  
B^LS^CCq^Li

Vb^LC^s X%L4%? G<C\ 4Cq{ E| EEu



, ^@Cp yPCsq-e pSWbY@fsc|c\_c\_g



# Acknowledgements

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R..b~Y@ YbC zb Cteqss \ %@Cce - eeqC-S zB^ Hbq \ %s~eCqfSbq>, ^@qG 3~q zzS  
- ^@ 3- q4 q „ C4Cq Hbq zPCq LqG z L~S@ ^<C - ^@ <b^szq<SjC HCC@4 <W@-qS^L zPC  
eqUCzi , seC-S YzP- ^W sPb~Y@ 4CLSjC^ zb, ^@qG 3~q zzS Hbqz- W^L zPCzS\ C- ^@  
C bqz bHeqfS^S^L f- Y- 4Y- @fS-C- ^@L~S@ ^<CS^ zPC@%@b@%o.bqWb^ zPCzPGsS>  
- ^@ Hbq PS C^<b-q LC C^zs - ^@ zC^P^S- YCteCq^S^S^ zPCqCq qP ” C@>..PS^P P- fC  
4CC^ bHLqG z sL^S < ^<C zb zPC C^@ qS~Yi R..b~Y@- Yb YbC zb zP- ^WzPCyG^P^S- Y  
} ^SjCqS^%bH? C^ \ - q^WbqeqfS^S^L zPC Hq \ C.bqWbq <b^@<S^L zPCzPGsS ..bqW  
GS- Y^aR..SP zb zP- ^W\ %H\ S^%Hbqs~eebqS^L \ CzPq-LPb~z \ %sz~@Ss - ^@  
zPC zPGsS ..bqW- ^@ dCq, q^C pSWbY@ Hbq sb LC^Cq~sY%b^ CqS^L zb eqbHq @ zPC  
zPGsS @-qS^L Ss ” ^- Ysz- LCsi









# CHAPTER 1

## Introduction

3~sS'Gss eqp<Gss \ b@Cš - qC - ^ S ebqz ^z zbbYHhQ \ - ^%bqL ^S - zš^s> - ^@ - S@ S' z sVš s~<P - s @b<~ \ C^z - zš^ bHeq<C@ - cš>C^zCp qšC S^zLq zš^>eGqHhQ \ - ^<C - ^ - YQ %šš - ^@S ebpfC C^z q:> - ^@ - <z - s qHhQ<C \ b@Cš HhQ zPC <qz zš^ bHšS S' q eqpQ <GssGš Q | : i [ - ^%š%šzC \ s zP - z beCq zC b^ eqp<Gss \ b@Cš - Yš Cš Sz> s~<P - s \ b@CY C@šzbcq> sS ~Y zš^ zbbYš HhQ LC^Cq zS^L YLs>bq qšbszbcqš zP - z bqL ^S C - Y qL C sCz bH \ b@Cš Q Cš c{ : i y PšC s%šzC \ s bH^C P - fC - @f - ^<C@ - YLbqšP \ s HhQ eGqHhQ \ S^L beQ Cq zš^s S' fbYš^L eqp<Gss \ b@Cš [ b@CYC@šzbcq>HhQ S' sz - ^<C> \ SLPz - ^ - Y%C - \ b@CY zb <PC>WHhQ CqHhQ Q | : > - ^@ - Yqz zPC @GSL^Cq S' Hš @š<bjCqš - ^%o [ b@CYqšbszbcqš \ SLPz P - fC - \ CzPb@HhQ qš^L sS S' qš%šC q-PCš ..šP - seC-S < \ b@CY>zb " ^@bzPCq sS S' q \ b@Cš Q J > | D>J | > cJ : i

„ PC^ @CfCšbeS^L s~<P - YLbqšP \ s>š S S' ebqz ^z zb zCsz zPC \ >zb sCC Pb....CY zPC%eGqHhQ i y Pšš <b~Y@ \ G ^ zCsz^L zPCq <bqšz^Gss b^ - <Cqz S' sCz bHeq<Gss \ b@Cš> 4-z <b~Y@ - Yš \ G ^ zb zCsz zPCq eGqHhQ \ - ^<C> seC-S < Y%šPCq - fCq LC eGqHhQ \ - ^<C> 4%š-4CzS^L zPC \ zb - 4C^<P \ - qW \ - @C - e bH <bY<zš^ bHeq<Gss \ b@Cš Cš PššS^L qCšf - ^z <P - q <zCšzšs q c : i Cbq - ^ CqHhQ <PC>Vš^L - YLbqšP \ >HhQ Cš - \ eY<š \ SLPz 4C @Gšq 4Y zb zCsz š b^ - q ^LC bH@š Cq^z eqp<Gss \ b@Cš bH - Y qL C sS C>zb @Cq \ S^C zPC - fCq LC eGqHhQ \ - ^<C - s zPC sS C bHPC \ b@Cš S^ l ~Gszš^ Lq. . si RHzbb s \ - Y \ b@Cš - qC <PbsC^> zPC 4C^<P \ - qW. . S Y^bz 4C qCšf - ^z zb ..P - z š S s - eebšC@ zb 4C zCsz^L - ^@ Hhbb sS S' q \ b@Cš - qC <PbsC^> š ..S Y 4C @š <~Y zb @q ... - ^%š^<Ysš^ - 4b - z Pb...zPC - YLbqšP \ \ SLPz eGqHhQ \ b^ @š Cq^z \ b@Cš bHPC s - \ C sS C>sb š \ SLPz ^bz 4C Hšq zb bzPCq s%šzC \ s ~s^L zPC s - \ C 4C^<P \ - qW Rš S zPCqHhQ S' ebqz ^z zb <PbsC zPC qšLPz eqp<Gss \ b@CY <bY<zš^ ..PC^ <qz zS^L - l -- Yš%4C^<P \ - qW

R - @šš^ zb s%šzC \ s zP - z ..bqWb^ @šCzY%b^ zPC \ >eqp<Gss \ b@Cš < - ^ - Yš 4C ~sCHY. .šP S' eqp<Gss \ S^S^L Q : > ..šP Sš - @š - š Y C zP - z - ^ - Y%š YLš HhQ \ 4~sS' Gss eqp<GssSi y Pšš < ^ S' fbYšC>HhQ Cš - \ eY<@Cq \ S^S^L Pb....CY - eqp<Gss <b^HhQ \ s zb šš @C ^šš^ S' eq <zšC> S G eqp<Gss <b^HhQ \ - ^<C <PC>Vš^L > ..šP zPC ~Yš - zC Lb - Y bHš eqpš^L zPC \ b@CY@š<qš^L zPC eqp<Gss i „ PC^ ..bqW^L ..šP eqp<Gss \ S^S^L - YLbqšP \ s>š Sš bH^C ~sCHY zb P - fC zPC eqš<qš^L @ eqp<Gss zP - z - sCz bHšL 4Cš^L zb>sb š < ^ 4C ~sC@ - s - qHhQ<G r ~<P - qHhQ<C š - Yš bH^C ~sC@ - s - Lq - ^@ zq - zP ..šP zPC qš - Yš bHPC - YLbqšP \ < - ^ 4C <b \ e - qC@ z i „ PC^ Cš - Y - zS^L - eqp<Gss @š<bjCqš YLbqšP \ > ..šP Sš - ^ - YLbqšP \ zP - z - zC \ ezs zb qC^>szq - z - eqp<Gss @C ^šš^ HhQ \ šš YLs>P - fS^L - qHhQ<C zb <b \ e - qC zPC @š<bjCqš @ \ b@CY zb š fCqš ebqz ^zi pCqš^L zb - Lq - ^@ zq - zP šš bH^C fš - Y zb zPC Cš - Y - zš^ bH

zPCl ~- Y%bH eqp<Css \ S'S'L - YlbqzP\ 9:i

yPCeqp<Css ~sC@- s - Lqb- ^@zq-zP LC^Cq Y%<- ^ ^bz U-sz 4C - ^%eqp<Css \ b@CY XSW...SP - YlbqzP\ s zP-z beCq zCb^ eqp<Css \ b@Ck>eqp<Css \ S'S'L - YlbqzP\ s - qC zCsz@bq 4C^<P\ - qW@b^ YLs zP-z <b\ C Hb\ eqp<CssCs zP-z CjPSAsz <Cqz- S' @CsqC@ <P- q <CqszSsi Rz \ SLPz 4C bHe- qz~- Yq S'zCqsz zb zCsz - eqp<Css @s-bjCq%o YlbQ qzP\ b^ YLs LC^Cq zC@ Hb\ - eqp<Css zP-z <b^z- S's @C @b-Vb\ Hbq Cj- \ eYi yPSs - Ysb \ G ^s zP-z <PbbsS'L eqp<Css \ b@Ck zP-z CjPSAsz <Cqz- S' <P- q <CqszSs Ss - s S\ ebqz ^z S' eqp<Css \ S'S'L>- s Sz Ss S' bzPCq- YlbqzP\ si

yPCqC- qC \ - S'Y%z. b...%bHb4z- S'S'L eqp<Css \ b@Ck zb ~sCHbqzCszS'L bq 4C^<PQ \ - qW\ L - ^ - YlbqzP\ >4bzP ..SP zPCqj - @f ^z- LGs - ^@@s- @f ^z- LGs q | :i a ^CSs zb sCQ-z zPC \ b@Ck Hb\ - ^ CjSzS'L sb~qC~s~<P - s - e~4Y%o f- SY 4Y eqp<Css \ b@CY qebszbq%o yPSs - Yb..s @CjCbeCq zb l ~S'W%o zz- S' ~s- 4Y \ b@Ck zP-z ~s~ Y%qCeQ qCs^z qC YqH eqp<CssCs> 4-z <b\ Cs ..SP zPC @q ..4 <WbHqC@~<C@ • CjSAs%o ^@ <b^zqbYb/Cq ..P- z W@bH\ b@Ck - qC ~sC@ Gbq Cj- \ eY> zPC @CjCbeCq \ SLPz P- fC Hb- ^@ \ b@Ck zP-z @SeY%zPC @CsqC@ <P- q <CqszSs> 4-z zPCsCz Ss ^bz bH @Q ~- zC sS G~bq Ss bzPCq. SCS' - @Q ~- zCHbq @q ..S'L <b^<Ysb^s- 4b-z zPC- YlbqzP\ s eCqHbq \ - ^<G yPSs \ G ^s zP-z zPC @CjCbeCq ..SY- fC zb YbW Hbq bzPCq \ b@Ck zb \ - W ~e Hbq <- qC^z sPbq <b\ S' Ls...PSP <- ^ 4C fCq%zS Cqb^s- \ S'L>HCfC^ ebssSYC- ^@ \ SLPz YC @zb <PbbsS'L s-4QezS\ - Y\ b@Ck yPSs eqp4Y\ S Cj- LLq zC@ 4%zPC H<z zP-z \ - ^%d b@Ck - qC <YsC%L~ q@C@zq @CsC<qzS bHzPCq qeGzSfC <b\ e- ^Ss>bq <b^z- S' eCqsb^ - YbqS^sSfC S' Hbq\ - zsb^>sb zPC ^~\ 4Cq bHe~4Y%o f- SY 4Y qC YqH eqp<Css \ b@Ck Ss Ys S' C@ Qj :i

, ^bzPCq ...%bHb4z- S'S'L s~S- 4Y eqp<Css \ b@Ck Ss zb ~zb\ - zS- Y%LC^Cq zC zPC i yPSs - eeqp<P Ss Pb..CfCq szp^L Y%o@CeC^@C^z b^ zPC LC^Cq zsb^ - YlbqzP\ ~sC@- ^@Ph....CYs <- ^ LC^Cq zC eqp<Css \ b@Ck zP-z CjPSAsz zPC @CsqC@ <P- q <CqCq SzSsi yPCqC- qC sCfCq YeqebsC@ sbY-zb^s Hbq s~<P eqp<Css \ b@CYLC^Cq zbq> s~<P - s zPC 4- sS b^C S^zY@C@ S' zPC dqb<Css XbL K^C^Cq zbq fdXKq 9:i yPSs LC^Cq zbq @C^Gs - sCz bH- sS e- zCq^s zP-z - qCzCq zSfC%o PbsC^ @- q^L LC^Cq zsb^ bH \ b@Ck 4- sC@b^ - eqC@CzCq\ S'C@ eqp4- 4Ss%o ssL^C@ zb G <Pi ,, PSC sS eY> zPC LC^Cq zbq @bCs ^bz eqpfS@C zPC ~sCq ..SP - PSLP @CqC bH<b^zqbYbHzPC <P- q <CqszSs zP-z zPC LC^Cq zC@ eqp<Css \ b@Ck ..SY @SeY%o- s zPC LC^Cq zsb^ eqp<Css b^Y%z- Ws zPC - ssL^C@ eqp4- 4SsSs - s S'e~zi yPC ..bqWbHf ^ OCC Cz - Y qeC q\ C@Ss zPs 4%o @CzCq\ S'S'L zPC S'e~z eqp4- 4SsSs 4%o@C~\ ebsS'L - <bYc-zsb^ bH\ b@Ck zP-z @SsQ eY%zPC @CsqC@ <P- q <CqszSs si ,, PSC zPC%o <PSCfC PSLPCq <b^zqbYbHzPC LC^Cq zC@ \ b@Ck 4%o HSPH Y%qCeq@- <S'L zPC <P- q <CqszSs bHzPC qHfC^ <C <bYc-zsb^> zPC \ CzPb@ qL ~SfS ~sCq zb 4C S' ebssCsb^ bH- qHfC^ <C <bYc-zsb^ ..SP zPC @CsqC@ <P- q <CqszSs>..PSP S' ^bz- Y.: %zPC<- sC>bqS q-PS'L Hbq b^C \ SLPz 4C Cj zC^sSfC%o zS Cqb^s- \ S'L bq @S <- Yi yPSs Ss - Ysb zq- C HzPC <P- q <CqszSs bHzPC <bYc-zsb^ P- fC zb 4C - @U-szC@ sYLPz%o Hb\ - ^ - f- SY 4Y <bYc-zsb^ i

yPSs ..bqW- Ss s zb <qC zC- LC^Cq zsb^ \ CzPb@ Hbq 4-sS Css eqp<Css \ b@CY<bYc-Q zsb^s zP-z eqpfS@Cs S' <qC sC@ <b^zqbYbHzPC <P- q <CqszSs bHLC^Cq zC@ <bYc-zsb^s> 4%z- Ws L zPC @CsqC@ <P- q <CqszSs bHzPC LC^Cq zC@ <bYc-zsb^s- s S'e~z S' zPC Hbq\ bH CzqfSsi Gq\ zPCs \ CzqfS> zPC eqp4- 4SsSs Hbq <PbbsS'L G <P 4- sS e- zCq^ ..SY 4C @CzCq\ S' C@- ^@ <b^zS' ~b-sY%o e@ zC@ Hbq G <P S' Cq zsb^ bHzPC LC^Cq zsb^> 4- sC@

b^ zPC <~qf^z sz-zC bHG <P LC^Gq zC@ \ b@CY<b\ e-q@> zb zPC @Gsfq@ b^G R^ - @SQ  
 zS^ zb CS S'-zSL zPC^CC@ HhQ P-fS'L - ^ -f-SY 4Y \ b@CY<bYC-zS^ ..SP zPC @Gsfq@  
 <P-q <ZGfzSs> zPS \ CPh@ e~zs zPC ~sCq S @Gfz <b^zqbYbH..P-z <P-q <ZGfzSs  
 LC^Gq zC@ <bYC-zS^s ..SY@SeY%o

yPC qsz bHzPC zPGsS eqsC^zs zPS - eeq <P S' zPC HhYb..S'L \ - ^^Gq ; P- ezCq  
 | e~zs zPC eqebsC@ - YlbqfzP \ S' zPC <b^zCqz bHCfzSzSL qCsG qP S' zPC "CY@ - ^@  
 <P- ezCq { eqsC^zs - ^~\ 4Gq bHeqCS S'-q%«b^<Gezs zP-z - qC qfGq^<C@ S' zPC qsz  
 bHzPC zPGsSi ; P- ezCqJ eqsC^zs zPC - YlbqfzP \ - ^@ <C^zq Y<b^<Gezs> 4CHqC <P- ezCq  
 I eqfS@Cs - ^ bfGqfSC...bHfzS S eY \ C^z-zS^i Gq \ zPS S eY \ C^z-zS^> zPC qS- Ys  
 eqsC^zC@S' <P- ezCqv - qb4z- S' C@> ..PS-P - YbeqfS@Cs - @S<~ssS^ bHCfGq Y-seC-zs  
 bHfzS eGqHq \ - ^<G GS- Y%o <P- ezCq u eqfS@Cs - s~ \ \ - q%bHzPC zPGsS - ^@ Yszs  
 s~LLGszS^s HhQ Hz~q cCsG qP S^zb zPC zbeSi

yPS e-LCP-s 4CC^ S^zC^zS^ - Y%CH 4Y^W

# CHAPTER 2

## Related Work

yPGcP-fc4C^ sCfCq YecfSb-s..bqWz <Vb^L zPC ep4Y\ bHL^Cq zS^L 4~sS^C  
ep<Css \ b@Cxi r\b C bHzPGC LC^Cq zbq - q l ~S< 4 sS> - ^@ - q b^%e- qz bH  
- \ bq <b\ eqPC^sS^C qS< qP Hb<-si a ^C s~<P LC^Cq zbq S zPC b^C S^<Y@C S^  
zPC dqb<Css Xbl K^Cq zbq fdXK g 9r:><-qq^z%S^ Ss sC<b^@ S<Cq zS^ - s dXK | 9:>  
..PS^P eqebsCs - LC^Cq zbq Hbq \ b@Cxi zP-z - qC ~sC@ zb LC^Cq zC YLs Hb\ >sCqS^L  
-s - Lqb-^@ zq-zP Hbq zPC YLsi yPS LC^Cq zbq ..bqW 4%@C^ S^L - <b^zC^zQCC  
Lq \ \ - q ep@<S^L ep<Css \ b@Cxi> - ^@<CqS^L - sCz bH4 sS e-zzCq^s Hb\ zPC  
<b^zC^zQCC Lq \ \ - q ? ~q^L C^C<-zS^> zPC sC e-zzCq^s - qC qC<-qS^C%ep@<C@ S^  
zPC \ b@CY~^zS^b \ bqCs% 4bY - qC YH i ,, P-z e-zzCq^s - qC<Pbs^ @Ce^@s b^ - sCz  
bHeq@CzCq S^C@..CSPz bHC <P e-zzCq^>..PS^P @Sz zCzPC ep4 4S^S^Cs bH<Pbbs^L  
G <P b^G , sS S^q LC^Cq zS^ - YlbqP\ S zPC b^C S^ 9J:>..PS^P q ^@b\ %PbbsCs  
b^CbHScfCq Yq^ ^C C^z q-Ys - s @C^@S^ 9CE- ^@~sCs zPCLC^Cq zC@ \ b@Cxi S^ - ^  
S^@C^S^L - YlbqP\ i ,, PSC 4CS^L - 4Y zb l ~S^W%LC^Cq zCY qLC - ^@q ^@b\ ep<Css  
\ b@CxiCs>zPC%epfS^C YzZC @S^z <b^zqYb^fCq..P-z <P-q <ZCfszSs zPCLC^Cq zC@  
\ b@CY<bY<zS^s..SYP-fG

, sS S^q ep<Css \ b@CYLC^Cq zbq S @C^@S^ 9\_i Ob.CfCq zPS LC^Cq zbq S  
seC-S^ <Y%@CS^L^C@ zb LC^Cq zC ep<Css \ b@Cxi Hbq <qC zS^L 4C^<P\ - qW> - ^@zP-s  
epfS^Cs sb\ C \ bq <b^zqYbHPC LC^Cq zC@<P-q <ZCfszSs 4%Yb..S^L~sCq zb <PbbsC  
4Cz..C^ @S Cq^z <YssCs bH..bqWb...^Czi yPGC <^ 4C CS^PCq T- <Vb^Q C> sz zC  
\ - <PS^C^C> \ - qW@q ep^Cz - ^@ HqCqPbs^C^C> - ^@<C^C..P-z e-zzCq^s>bq  
<b^zq<S^ q-Y>..SY4C-f-SY4Yi yPC Hq \ C..bqWbHPC LC^Cq zbq - Yb - Yb..s Hbq  
- s-4sCz bH..bqWb...^Cz zP-z P-fC <Cqz S^ <P-q <ZCfszSs zb 4C <Pbs^ Hb\ zPC  
s-eCqz bH YL^Cq zC@ \ b@Cxi ? CseS^C epfS^S^L S^<qC sC@ <b^zqYbHPC b-ze-z  
<P-q <ZCfszSs> zPC - YlbqP\ szSY qd ~S^Cs zPC ~sCq zb seC-S^zPC ep4 4S^S^Cs bH  
- eeY^L C <P <b^zq<S^ q-Y>..PS^P S^ zPC @C^Cq S^Cs ..P-z <P-q <ZCfszSs zPC  
..bqWb...^Cz..SYP-fG

yPC..bqW^S^ 9CE C^z^@s zPC..bqWbHq\_ : 4% ^- %S^L C^S^S^L ep<Css \ b@CY  
<bY<zS^s zb ^@zPCq LC^Cq zS^ e-q \ CzCp>S^G zPC ep4 4S^S^Cs - ssL^C@ zb C <P  
<b^zq<S^ q-Y S^ bq@Cq zb LC^Cq zC sS S^q \ b@Cxi 3% ^- %S^L - <bY<zS^ bH  
^Cz ..SP Wb..^ <P-q <ZCfszSs> zPS - Yb..s zPC LC^Cq zS^ bH- 4SLLq <bY<zS^ bH  
^Cz ..SP sS S^q <P-q <ZCfszSs> yPS S - \ - UbqS epfC C^z <b\ e-q@ zb eqfSb-s  
..bqW 4-z szSYb^%epfS^Cs S^@S^z <b^zqYbHPC LC^Cq zC@<P-q <ZCfszSs> sS^<Cz  
qd ~S^Cs - <bY<zS^ bH^Cz ..SP zPC @CS^C@<P-q <ZCfszSs b^Q- ^@ R^ <b^zq sz zPC  
\ CzPb eppebsC@ S^ zPS zPCs q\ bfCs zPS \ S@C Y^W epfS^S^L @S^z <b^zqYbH

zPCep@~<C@<P-q <zCszSs>4%o Yb..S'L ~sCq zb @sqzY%seC<S%zPC\ i  
 yPC ..bqWS' 9J{ : - ^@ 9J: - Ysb @C Y' ..SP ep<Css \ b@CYLC^Cq zSb^> 4~z zPCsq  
 Hb<~s S b^ zPCY4C' - ^@^-\ S'L bHzPC<b\ eb^C^zs S' zPC\ b@C'>q zPCqzP- ^ zPCsq  
 szq~<z~q>..PS-P S zPC Hb<~s bHzPS zPCsSi



# CHAPTER 3

## Background

yPCzPGSS \$ z qLzC@ zb.: q@s qG @CqP zP- z P- fC- 4 <Vlq~^@ ..SPS^ <b\ e~zCq s<SQ C^<C>- ^@ zPC qSz bHzPC ..bqW..SY~sC zPS -s- 4 sCS^G , s s~<P>S -ss~\ Gs zP- z qG @CqP P- fC- ^ ~^@CqPz ^@S^L bH4- sS< <b^<Cezs ..SPS^ " C@s s~<P- s Lq eP zPCbq%o -YbqfzP\ s>eq<Css - ^@sbHz..: qC \ b@CS^L zC-P^S ~Cs>- ^@eqS^<SeYs bHsbHz..: qC @CQ sSL^i

yPCzPGSS @bGs Pb..CfCq qL ~SfC <Cqz S^ eqCS^ S^<fCs seG^S^< zb zPC " C@bH4-sSQ ^Gss eqp<Css \ b@CS^L>..PS-P <- ^ ^bz 4CCf eCzC@4%cfCq^b^C..SP- <b\ e~zCq s<SC^<C 4- <Vlq~^@ R^ bq@Cq zb -eeG Yzb s~<P qG @CqP zPS sCzSb^ eqCS^zs sb\ C4- sS< <b^Q <Cezs zP- z zPC qSz bHzPC zPGSS -ss~\ Gs zPC qG @Cq zb 4CH\ SS q..SPi yPC <b^<Cezs -qC ^bz eqCS^zC@S^ @CezP>4-z S \ G ^z zb LSfC zPC qG @Cq- 4- sS< ~^@CqPz ^@S^L bH zPC <b^<Cezs QU-sz C^b-LP zb 4C- 4YC zb H^W%o^@CqPz ^@ qLqC^<Cs zb zPC \ -zCf Y YzCq S^ zPC zPGSSi

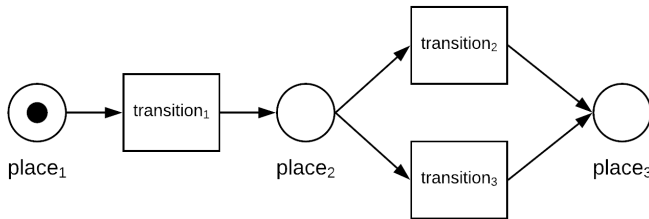
### 3.1 Process Models

„ bqWb...e-zzCq^s>- ^@S^ z-q^ ..bqWb... \ b@CS^> Hbq \ zPC 4- sS bH4-sS^ Css eqp<Css \ b@CSi yPGSC4- sS< ..bqWb...e-zzCq^s @Cs<f4C4- sS< <b^zq^Yb...>..PS-P <- ^ 4C~sC@ zb \ b@CYqG YfC eqp<CssCsi } ^Yss bzPCq .SsC sz-zC@> zPC S^ Hbq \ -zSb^ eqCS^zC@ S^ zPS sCzSb^ S qeep@~<C@ Hb\ 9ui

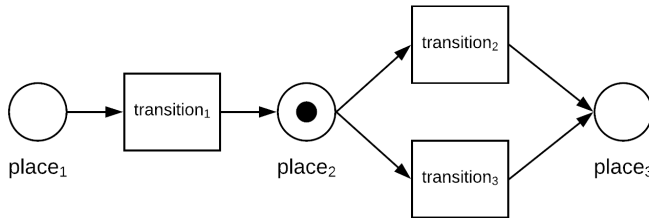
R^ bq@Cq zb eqCS^z s~<P- 4- sS< ..bqWb...e-zzCq^>- Y^L~ LC S^ ^CC@C@ [ - %o ..bqW^ ~sCsb\ C Hbq \ bH- dCzq^<Cz>..PS-P S fCq%o~S- 4YC Hbq zPS z-sW@-C zb zPCq sS eY^<bz-zSb^ - ^@<b^zq^Yb...>Hb<-si Ob..CfCq zPCq- qC bHzC^ sCfCq YbzPCq- seCzS bHzC YfC eqp<CssG zP- z \ b@CYqP ... ^z zb qeCqCS^zi yPGSC <- ^ S^<Y^@CS^ Hbq \ -zSb^ -4b-z ..P- z <Cqz S^ -<SfSSG bq z-sW bH- eqp<Css @b>..Pb eCqHbq \ s zPC >bq ..P- z sz- qz zPC i yPS \ G ^s zP- z \ b@CYqP bHzC^ ... ^z - Y^L~ LC ..SP \ bq C^eqCS^fCQ ^Gss zP- ^ dCzq^<Cz zb @Cs<f4C zPCq eqp<CssG>bH.PSP sCfCq YC^Szi yPS zPGSS ..SY \ bsz%oHb~<s b^ 3~sS^ Css dcp<Css [ b@CS^L ] bz-zSb^ f3d [ ] g-4-z bzPCq Y^L~ LC> s~<P- s BfC^z@CfC^ dcp<Css; P- S^ fBd; g- ^@3~sS^ Css dcp<Css B^C~zSb^ X- ^L~ LC f3d BXg- Yb C^Szi

### 3.1.1 Petri Nets

$\text{place}_1 \xrightarrow{\text{transition}_1} \text{place}_2 \xrightarrow{\text{transition}_2} \text{place}_3$   
 $\text{place}_2 \xrightarrow{\text{transition}_3} \text{place}_3$



f-g, dCz\$^Cz...zP - zbV^ - z place1



f4g y PC dCz\$^Cz bH{icf-g-HCq " q\$^L transition1> zq^stf\$^L zPC zbV^ zb place2

$\text{place}_1 \xrightarrow{\text{transition}_1} \text{place}_2 \xrightarrow{\text{transition}_2} \text{place}_3$   
 $\text{place}_2 \xrightarrow{\text{transition}_3} \text{place}_3$

$\text{place}_1 \xrightarrow{\text{transition}_1} \text{place}_2 \xrightarrow{\text{transition}_2} \text{place}_3$   
 $\text{place}_2 \xrightarrow{\text{transition}_3} \text{place}_3$

### 3.1.2 BPMN

$\text{place}_1 \xrightarrow{\text{transition}_1} \text{place}_2 \xrightarrow{\text{transition}_2} \text{place}_3$   
 $\text{place}_2 \xrightarrow{\text{transition}_3} \text{place}_3$

zPC HbYb..S'L 4-sS< b^zpbYQb...b4UC-zs < ^ 4C ~sC@ zb < ez-qC zPC <C^zq Y-seGzs bH \ - ^%da b@Cxi

, <SfSsCs yPC \ bsz 4-sS< b\ eb^C^z bHzPSs VS@Ss - z sW/a zPCq b\ eb^C^z bH zPSs < zCbqf%o qC s-4Qcp<CssCs - ^@< Y- <SfSsCs>4-z zPGsC - qC ^bz S' Hb<-s S' zPSs ..bqW y PCqHbq> zPC zCq\ s z sW ^@ - <SfSs%o.SY4C ~sC@ S' zCqP- ^LC 4Y%o zb \ G ^ - z sW

K- zC..%o yPGsC CC\ C^zs sL^ - YzPC se YszS'L bq Ubs^S'L bHCfG<-zb^ e- zPsi yPC CC\ C^zs zP- z ..SY4C ~sC@ S' zPSs ..bqW- qC e- q YCY- ^@ C^<YsSfC L- zC..%o - Ysb qCqC@ zb - s , | ? Qbq † a p Q- zC..%o ai a zPCq L- zC..%o S' <Y@C CfC^zQ 4- sC@L- zC..%o zP- z @SfC-zs eq<Css C^G<-zb^ 4- sC@b^ - ^ CfC^z P- eeC^S'L>bq S' <YsSfC L- zC..%o ..PGcC b^@Sb^s b^ <PbbsS'L - Ye- zPs - qC Cf- Y- zC@

BfC^zs yPGsCC\ C^zs S'@S- zCsb\ CZPS'L P- eeC^S'Li yPSs ..bqW..SYHb<-s b^ sz qQ - ^@ C^@CfC^zs>4-z - ^ S'zCq\ C@S zCfC^z sL^ - YS'L - ^ CfC^z b<<-qfS'L @-qS'L eq<Css C^G<-zb^ Ss - Ysb @C ^C@

rC ~C^C • b.. yPSs CC\ C^z- S'@S- zC@ - s - ^ - qp.....SZP - sbY@ Y^C 4Cz..CC^ • b.. <b\ eb^C^zs S' zPC \ b@C^ S'@S- zC zPC ebssS4Ss%bHzq ^sSb^S'L Hb\ b^C <b\ eb^C^z zb - ^bzPCq

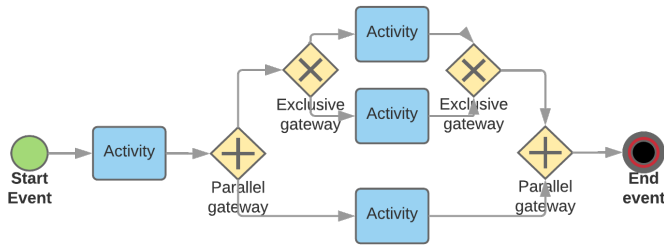
, sSc Hb\ zPC - 4bfC YszC@ b4UC-zs> 3d[ ] - Ysb P- s s..S\ Y^Cs - ^@ - qSH<zs> ..PS-P LSfC Sz zPC - 4Ss%zb < ez-qC - @Sb^ - Y- seGzs bHqC YqC 4-s^Ss eq<CssSi r..S\ Y^Cs - Yb...Hbq \ b@C^S'L zPC qseb^s4Ss%Cs bH eq<Css>SG ..Pb Ss qseb^s4Y C HbqeCqHbq S'L zPC <b^z- S' C@z- sW> ..PSC - qSH<zs>s~P - s @z- b4UC-zs - ^@ - ^bz- Q zb^s>< ^ 4C ~sC@ zb - @Cfzq S' Hbq\ - zb^ zb zPC \ b@CY R- Ysb Yszs bzPCq z%Gs bH <b^CzS^s 4CsScsC ~C^C • b..s>s~P - s \ Css- LC • b..si Ob..CfCq zPC Hb<-s bHzPSs ..bqW..SY - S' Y%4C ..SZP qL- q@s zb zPC - 4bfC YszC@ <b^zpbYQb...b4UC-zsi ,, SZP b^Y%o zPGsC 4-sS< b4UC-zs> Sz Ss G s%zb @q ...e- q YCs 4Cz..CC^ zPC qCs- YS'L 3d[ ] \ b@C^s - ^@ 4-sS< ..bqWb... \ b@C^s Cf eqCssC@ - s dCzq^Czi

, ^ C^-\ eY bH- 3d[ ] \ b@CY~sS'L 4-sS< b^zpbYQb...b4UC-zs < ^ 4C sCC^ S' "L-qC{i|i , s sPb..^ S' q u>- 3d[ ] \ b@CY~sS'L zPGsCC\ C^zs ~s~ Y%P- s - 4-sS< dCzq^Cz ..bqWb...d ~Sf- Y^zi

### 3.1.3 Behavioral Properties

Rz Ss bHzC^ ~sCHYzb @Cs<qf4C..bqWb... \ b@C^s S' zCq\ s bHzPCq 4CP- fSbq YeqbeCqzSsi yPGsCeqbeCqzSs - qC^bz zb 4C <b^HsC@..SZP eq<Css \ b@CY-P- q <CqszSs>- s @C ^C@ S' sCzSb^ {i|i yPC \ bsz qCf- ^z eqbeCqzSs Hbq zPSs ..bqW..SY4C eqCs^zC@ S' zPSs sCzSb^i R' LC^Cq Y 4CP- fSbq YeqbeCqzSs bH\ b@C^s < ^ 4C @SfSsC@ S' zb zPC HbYb..S'L Hb-qeqbeCqzSsi

pC <P- 4Ss%o yPSs VS@ bHeqbeCq%ss - 4b-z - s%sz\ s ebssS4Ss%bHzC - PPS'L - <Cq- S' sz- zG R' zPC <b^zCfz bH4-s^Ss eq<Css \ b@C^s> Sz \ - Ws sC^sC zb



GS~c{ i| = B+ \ eY bH- 3d| ] @SLq \ i B-<P bHzPC •b... b4U<zs ~sC@ P- fC  
 4CC^ Y 4CC@ ...SZP zPCq cseC-zfC z%eCsi yPS ..bqW..SYH<-s b^ zPC  
 <b\ eb^C^zs ~sC@S^ zPS^ " L-q

z- YW- 4b-z zPC cC <P- 4SS%bH- ^ - <SfS%...PS-P \ G ^s zP-z SHzPC - <SfS%SS  
 <b^z- S^C@S^ zPC \ b@CY S sPb~ Y@ 4C ebsS4YC zb 4C cC <PC@ @-f^L C^G~zS^i

r - HZ%y PS WS @bHeqpeCq%SS - 4b-z zPC- 4sC^<C bHsb\ CzPS^L ~^@Gsq 4YCP- eeC^Q  
 S^Li R^ zPC <b^zC^z bH4~s^C ss eq<C ss \ b@CY> zPC - 4sC^<C bH@G @Y<W^S - ^  
 S^ ebqz ^z s- HZ%e qpeCq%o , @G @Y<W^S - sSz-- zS^ ..PCq zPC s%sz\ LCzs  
 sz~<W^s~<P zP-z S^ S^ ~^< 4YC zb <b^zS^~G R^ zCq\ s bH- 3d| ] \ b@CY zPS  
 <b~Y@ b<<-q SH- e- q YCYL- zC.: %SS^ S^ ... S^S^L Hqz .b eq<C@S^L - <SfS^S^S^ zb  
 4C cC <PC@> 4-z - ^ C^<Y-ssfC L- zC.: %se YZ G qYq S^ zPC •b... \ G ^s b^C bHzPC  
 - <SfS^S^S^ ..SY^CfCq 4C cC <PC@

XSfC^ C ss 3%C^s- fL YfC^ C ss eqpeCq%SS bH s%sz\ >S^ S^ C^s-qC@ zP-z zPC s%sz\  
 eqLqC ss C si , <b\ \ b^ s- <P eqpeCq%SS zPCL-- q ^zCC@zCq\ S^ - zS^ bH s%sz\ >  
 GLi zPC s%sz\ cC <PS^L - ^ C^@CfC^z S^ - 3d| ] \ b@CY

G- S^f C ss yPC HS^f C ss eqpeCq%SS eYCs zP-z - <PbS^C S^ ^bz SL^bC@ HbCfCq yPS  
 \ G ^s Hq C^< \ eY zP-z SH- ^ f^bq L- zC.: %SS e- qz bH- ^ S^ ^ ^SC Ybe> - YzPC  
 <PbS^C S^ ..SY^CfC^z-- Y%4Cz- W^> - ^ @ ^b^C SL^bC@ HbCfCq

R^ - @SS^ zb zPC eqpeCq%SS >D @S<-ssCs - sb~^@ C ss eqpeCq%ssz- zS^L zP-z  
 - sb~^@ eq<C ss C^s-cf s fcg - ^ bezS^ zb <b\ eYzC> SG cC <PS^L - ^ C^@Cz- zC f|g  
 <b\ eYzS^L eqpeCq%SS SG zPCq - cC ^b \ bC sz- zCs C^G~zS^L S^ zPC \ b@CY ..PC^  
 zCq\ S^ - zS^ P- eeC^s- ^@f{gzPCq - cC ^b @C @zq ^sS^S^>SG - ^%o qS^zq q%o <SfS%o  
 <- ^ 4C cC <PC@ y PC%qHq zb zPS WS @bHsb~^@ C ss - s <YssS- Ysb~^@ C si B^s- fL  
 eqpeCq%fcg S^ eYCs HS^f C ss>- ss- \ S^L zP-z - YebssS4YC <PbS^C S^ - \ ~z-- YC^<Ysb^  
 L- zC.: %se YZ ...SY- Y.: %CfC^z-- Y%4C <PbS^C i Rz- Yb S^ eYCs s- HZ%4%zPC- 4sC^<C bH  
 @G @Y<W^S - ^@ zP-z zPC s%sz\ ..SY- Y.: %CfC^z-- Y%4Cq\ S^ - zG y PC sC b^@ - seCz  
 bHsb~^@ C ss S^ eYCs zP-z ^b bzPCq e- qz bHzPC s%sz\ S^ q- ^ ^S^L ..PC^ zPC \ b@CY  
 zCq\ S^ - zCs> - ^@ zPC zPS^ b^C S^ eYCs cC <P- 4SS% Hq C fCq%o <SfS%SS^ zPC eq<C ss  
 \ b@CY

### 3.1.4 Constructing Process Models

yPC CłSzsL eqp<Gss \ b@CYLC^Cq zbq \ C^zsb^@S^ <P- ezCq | ~sC - f- qCz%bHzC-PQ  
 ^S ~Gs Hbq - <z- W%LC^Cq zSL zPCq eqp<Gss \ b@Csi „ PSC zPCq CłSzs sb\ C..bqW  
 ..SPS^ zPC qYzC@” C@ bHLq eP s%zPGSS fs-<P - s Q: g- zPC <b^<Cezs P- fC b^Y%b<Q  
 <- sb^ - W%4CC^ - eeY@ zb ..bqWb... ^Cz LC^Cq zsb^i a ^Cs-<P - eeYs- zsb^ S S^ Gc:>  
 ..PCq zPC eqp<Gss LC^Cq zsb^ zC-P^S ~Gs bHq\_: ..Cq CłzC^@@ zb 4-s^Gss eqp<Gss  
 \ b@Csi

, ^bzPCqLC^Cq zsb^ zC-P^S ~CqYCs b^ zPC<b^szq<zsb^ q-Ys sz-@C@4%bCqPCbz  
 S^ G: - ^@r~<~W C- Y S^ q.v.i R^ Q\_> ^Cs <b^szq<zC@ Hb\ zPGsC q-Ys>..SP zPC  
 Cł<CeZsb^ bH- Ybe - @@zsb^ q-Y> - qC < Y@ T- <Wb^Q Csi r~<P ^Cs C^s-q zPC  
 sb-^@^Gss eqpCq%..PSP S eqpfC^ S^ QDi yPC <b^<CeZ bHsb-^@^Gss S CłeY^S^C@  
 S^ sCzsb^ {ici{i R^ Q\_>- ^ CłzC^sb^ bHzPS <b^szq<zsb^ q-YsCz S ~sC@zb LC^Cq zC  
 ..bqWb... ^Cz> ..SP ..PSP zPC% Yb eqpfC zP- z S S ebss^YC zb <b^szq<z- ^%dCzq  
 ^Cz> 4-z ..PSP @bCs ^bz eqCsCqfCsb-^@^Gssi

yPC 4- sS- q-Ys sz-@C@S^ G>{v: - qC< Y@| ~q z q-Ys>- ^@- qC^C^ @HbqdCzqS  
 ^Csi yPC q-Ys - qC YzC@- s pCqv S^ z 4C{ic>- ^@ \ - S^Y% @eY<G bqzq ^sSsb^s  
 zb zPC \ b@CY@-eYs- zSL zPC \ >bq- @@SL Ybesi R^ bq@Cq zb <b^szq<z- \ b@CYHb\  
 s~<P <b^szq<zsb^ q-Ys>zPC%P- fC zb 4C- eeY@ sCfCq Yz\ Gs zb - \ b@CY..PCq zPC  
 \ b@CYsz- qz - s - sSL-Yq ^Cz bHL-sz b^C^b@ 3%sb^sCz-zSfC% eeYSL zPC q-Ys  
 - z @S Cq^z eY<G bHzPC ^Cz> S ..SYLq @- W%Lq... 4SLCq- ^@ \ bqC <b> eYt>- ^zSY  
 zPC @Gsq@P- s 4CC^ <b^szq<zC@

R^ Q\_>JCE- ^ Cłzq sCz bHq-Ys> 4q@LC q-Ys>- qC- @C@ zb zPC | ~q z q-Ysi , s  
 zPC ^- \ C s-LLGsz>zPGsC q-Ys 4q@LC zPC \ b@CY4% @@SL - <b^<Czsb^ 4Cz..CC^  
 z.b sGe- q zC e- qz bHzPC \ b@CY „ PSC zPGC^C...q-Ys @b ^bz ^C-Gss- q%eqCsCqfC  
 zPCsb-^@^Gss bHzPC \ b@CY zPC% Yb... ^%dCzq^Cz zb 4C <b^szq<zC@

a zPCqLC^Cq zsb^ zC-P^S ~Cs S^<Y@CLC^Cq zSL..bqWb... \ b@Csi Hb\ - szb<P- szS<  
 <b^zCłzC@Cq \ \ - q- s S @b^C 4%dXK Q:i yPS - eedp <P S CłeY^S^C@S^ HqPCq  
 @C- SY^ sCzsb^ {i i

## 3.2 Metrics as Process Model Characteristics

R^ LC^Cq Y- \ Czq S - sz- ^@ q@ bH\ G s-q\ C^z ~sC@ zb l ~ ^zY% eqpCq%bH  
 sb\ CzPS^Li } ^YWC - \ G s-q>- \ Czq S ~s- W%bzb sb\ CzPS^L zP- z S \ G s-qC@  
 @CqzY%4-z S b4z- S^C@ 4%sb\ 4S^SL b^C bq \ bqC \ G s-q\ C^zsi Gbq Cł- \ eY>-  
 \ Czq Hbq zPC <-szb\ Cq s- zSH<zsb^ bH 4-s^Gss <b-Y@ 4C zPC- fCq LC q zSL>..PSP  
 S - <b> 4S- zsb^ bHzPC zbz- Yf- YC bHzPC q zSLs @SfC@ 4%zPC ^- \ 4Cq bHq zSLs>  
 LSfC^ zb zPC 4-s^Gss 4%sbz\ Cq zPq-LP - ..C4 ebqz- Ys-<P - s zPC b^C @S<-ssC@S^  
 Q\_{i yPGs\ Czq s- qC Hb-^@ zPq-LPb-z zPC s<C^<G>- ^@eY% ^ S ebqz- ^z qYCS^  
 l ~ ^zYSL eqpCqS bHqC qP S^ si Gbq zPC q\ - S^@Cq bHzPS zPGs>zPCq ..SY  
 ^bz 4C \ - @C- ^%@szs <zsb^ 4Cz..CC^ - \ Czq - ^@- \ G s-q..PC^ @S<-ss^L eqp<Gss  
 \ b@Csi ..PSP ..SY 4C qHq@ zb - s U-sz \ Czq-si , Yb> zPC zCq\ s <P- q <Cqszs<  
 - ^@ \ Czq ..SY 4C ~sC@ S^zCq-P- ^LG 4%zb qHq zb zPC <P- q <Cqszs bH- eqp<Gss

y- 4Y { ic= yPC<b^szq<zb^ q-Ys ~sC@S' 9\_>JfE yPC%P- fC4CC^ HqCY%qCep@-<C@  
 Hf\ zPCqHbq\ -Y@C^ sSb^s S' 9fE

p~Y	? Cs<qfzsb^
pc=dY<CqC^ ^C C^z	y~q^s - eY<CS^zb z.b eY<Cs <b^CzC@4% zq^sSb^
p =yq^sSb^ qC^ ^C C^z	y~q^s - zq^sSb^ S^zb z.b zq^sSb^s <b^Q ^CzC@4% eY<C
p{=Xbbe - @sSb^	, @as - ^C.. zq^sSb^ - ^@ <b^CzS z zb - eY<CbHzPC\ bCYzPq-LP- z.bQ.: %q
pJ=dY<C@-eYs- zb^	? ~eYs- zCs - eY<C- Y^L.. SP Ss - qs zb zq^Q sSb^s
pI=yq^sSb^ @-eYs- zb^	? ~eYs- zCs - zq^sSb^ - Y^L.. SP Ss - qs zb eY<Cs
pV=, qC^ ^C C^z	, @as - sD ~C^<CbH zq^sSb^ - ^@- eY<Czb - ^bzPCqsD ~C^<CbH zq^sSb^ - ^@- eY<C
pu=dY<C4q@LC	, @as - eY<C <b^CzC@ zb z.b zq^sSb^s>-z - ^%z.. b ebsSb^s bHzPC^Cz
pD=yq^sSb^ 4q@LC	, @as - zq^sSb^ <b^CzC@ zb z.b eY<Cs>-z - ^%z.. b ebsSb^s bHzPC^Cz
p_=, qC 4q@LC	, @as - ^ - qC 4Cz..CC^ - zq^sSb^ - ^@- eY<C> - z - ^%z.. b ebsSb^s bHzPC^Cz

\ bCY yPSs S' eYs zPC- ss-\ ezsb^ zP-z \ Czfs <- ^ H Y%@Cs<qfCzPC<P- q <Cqszs  
 bH- \ bCYs ..PSp \ - %dq \ - %^bz PhY@ zq-C @CeC^@S^L bH..P-z @C^ sSb^ bH-  
 <P- q <Cqszs S' ~sC@ Ob..CfCq HbqzPC e-qfbsGs bHzPSs zPCss>zPSs -ss-\ ezsb^ ..SY  
 4C \ - @G

[ Czfs P- fC 4CC^ C^zC^sSfCY%o-sC@ S' sCfCq Y- qC s bHqCsG qP qCYzC@ zb 4-ssQ  
 ^Css epq<Css \ bCYs^Li a ^CbHzPCsC- qC s S' ^Cz..bqW ^- Y%ss> \ C^S^L zPC" C@ bH  
 szq<~q YzPCbq%o.SPS^ - eeY@ Lq eP zPCbq%q {i, s zPSs ..bqWb~sCs b^ 3d| ] Q  
 \ bCYs>..PSp <- ^ 4C sCC^ -s- seC-S YV@ bHLq eP>- Yz bH..bqWf\ zPSs - qC  
 <- ^ 4C- eeY@ zb 4-sS^Css epq<Css \ bCYs [ Czfs ~sC@..SPS^ zPSs " C@ <- ^ 4C Hbq  
 C^ \ eY>zPC @C^sS%bq @sz ^<CbH ^Cz..bqW ? C^sS%ss @C^ C@ -s zPC ^~\ 4Cq bH  
 C@LGS S' - Lq eP><b\ e- qC@ zb zPC ^~\ 4Cq bHebssSYC C@LGS S' zPCs- \ C Lq ePi R'  
 zPC <- sCbH epq<Css \ bCYs zPC @C^sS%<b- Y@ 4C - ^ S^@s- zbq bHzPC <b\ eYt.S%bH  
 zPCepq<Css •b..>..PGCzPC \ bC<b^CzSb^s - epq<Css \ bCYP- s>zPC \ bC ebsSAYC  
 •b..st PC^<C- PSLPCq •b..<b\ eYt.S%o XSW..S< zPC @sz ^<C S' - ^Cz..bqW SG zPC  
 ^~\ 4Cq bHC@LGS S' - sPbqGsz e- zP 4Cz..CC^ z.b ^b@Cs><- ^ 4C-sC@ zb zCYzPC Y^LzP  
 bH epq<Css \ bCYs 4%bbV^L - z zPC @sz ^<C Hf\ zPC sz q zb C^@^b@G

a zPCq \ Czfs ~sC@ S' ^Cz..bqWzPCbq%o<- ^ - Yb 4C - eeY@ zb 4-sS^Css epq<Css  
 \ bCYs>s-<P -s @CqC<-C^zq Y%bq <b^CzSfS%o, HqzPCq C^eYq zb^ bH Czfs  
 Hbq4-sS^Css epq<Css \ bCYs^L- s..CY- s HbqzPSs epqCzS' e- qf~Y q..SY4CepfS@C@  
 S' sCzsb^ {i|ici

„ PC ~sS'L \ Czfs S' zPC " C@ bH4~sS'Gss eqp<Gss \ b@CS'L> ..PSp \ Czfs zb Hb<~s b^ \$ PSLP%@CeC^@C^z b^ zPCe~qpbsC bHzPC qfG q-Pi RHzPCe~qpbsCS qY zC@ zb S\ eqfS'L eqp<Gss \ b@CY@CSL^>S \ -W's sC^sC zb YbW-z \ Czfs qY zC@ zb zPC l ~ Y%bHeq<Gss \ b@CS>bq / ~ Y% Czfsi „ P-z \ -W's ~e s~<P \ Czfs>SG ..P-z \ Czfs <bqfY zC ..SP zPC s~4U<zSfC <b^szq~< bHl ~ Y%oS - \ -zzCq bHqG qP S' SsCYH ..PGC b^C \ SLz P- fC zb qfSbq zb PC-qfzSs bq YLS- Y- qL~ \ C^zs> q zPCq zP- ^ C eSf- YWb..Y@LG B†- \ eYs bH Czfs zP- z P- fC 4CC^ S'W@ zb l ~ Y% qC zPC ^~ \ 4Cq bH@Ss' <e- zPs S' zPC \ b@CY PSLq q-P%YfCS sPb..S'L zPC- \ b~^z bH ^Gsz'L> bq e- q YCS \ QI:i rCfCq Y..bqW S'WzPC l ~ Y% ^@ YWYpb@ bHCqf q S' - \ b@CY zb Ss <b\ eYfS%..SP zPC- ss- \ ezS^ zP- z PSLPCq <b\ eYfS% \ -W \ b@CS P- q@Cq zb <b\ eqPC^@ Hq @CSL^Cq> - ^@ zP~s Y@ @ zb - Y..Cq l ~ Y% ^@ PSLPCq YWYpb@ bHCqf q u> { : i yPS - Yb \ G ^s zP- z \ Czfs qY zC@ zb \ b@CY <b\ eYfS%> b\ eYfS% Czfs- qC- s- 4U<z bHz- @%S' sCfCq Y..bqW 9>D> { : i yPC ..bqWbH C^@S'L Q : zfs zb \ -W- @Ss' < b^CzS^ 4Cz..CC^ zPC <b\ eYfS% bH - \ b@CY- ^@ Ss YWYpb@ bHCqf q> - ^@ <b^<Y@Cs zP- z zPCq S' S^@C@- sL^S' < ^z <bqfY zS^i

### 3.2.1 Specific Metrics

R' Q { : > | C^@S'L @SfS@Cs eqp<Gss <b\ eYfS% Czfs S' zb sSf < zLbqf> Hq eqfS' z Q zS^ e~qpbsSi yPS ..bqW..SY~sCzPCs \ C< zLbqf> ..PSp - qC- s HbYb..si

**rS C R' <Y@Cs \ Czfs zP- z- ' Cz zPCsS C bHzPC eqp<Gss \ b@CY , ^ b4fS~s C†- \ eY S' zPC ^~ \ 4Cq bH^b@Cs S' zPC eqp<Gss \ b@CY ..PSp Hq \ bsz 3d | ] \ b@CS \ G ^s zPC ^~ \ 4Cq bH <zSfS% - ^@L- zC..%i Ob..CfCqS- Yb S' <Y@Cs \ Czfs s~<P- s Ss @ \ Czq**

? C^sS% PSC@C^sS% Hq- Lq eP S' s~s~ W%@C^ @C@- s zPCq zS bHzPC- <~ Y^~ \ 4Cq bHC@LGS zb zPC zbz- Y^~ \ 4Cq bHC@LGS> S' ..SY Hq zPS' ..bqW4C ~sC@ zb qfHq zb - ^% Czfs zP- z @Cs<fS' zPC ^~ \ 4Cq bH^ b@Cs qY zC@ zb zPC ^~ \ 4Cq bH qS> bq <b^Cz bqi a ^C s~<P \ Czfs S> bH<b- qC> Ss @C^sS% R' Pb..CfCq- Yb S' <Y@Cs zPC <bC <C^z bH^ Cz..bqWb^ ^CzSfS% SG zPCq zS bH qS zb ^b@Cs> zPC- fCq LC <b^Cz bq @LqC> SG zPC- fCq LC ^~ \ 4Cq bH^ b@Cs - <b^Cz bq <b^Cz z> - ^@ zPC \ - fS ~ \ @LqC> SG zPC PSLPsz ^~ \ 4Cq bH^ b@Cs - <b^Cz bq <b^Cz z> zbi

**d- qSb^ - 4S% yPS zCq\ S' ~sC@ zb qfHq zb zPC @LqC zb ..PSp - \ b@CY < ^ 4Ce- qSb^ @C^ S' zb s-4Qb\ eb^ C^zs> ..PSp < ^ 4CsCC^ S' SsbY zS^ Hb\ bzPCq e- qS bHzPC \ b@CY yPS <b- Y@ 4C zPC ^~ \ 4Cq bHr R'a Q- qS S' zPC \ b@CY bq Pb... \ - ^% ^CszS'L 4Y<W bHse YWbS' L- zC..% S' P-si R' zPS' < zLbq% [ C^@S'L S' <Y@C@ \ Czfs s~<P- s sC- q 4S% ..PSp S' zPCq zS bH<~zCqS' S' f- qS~<Y zS^ ebS' zsg zb - YfCqS' bH \ b@CY sL ~C^zS Y%..PSp S' zPCq zS bHC@LGS 4Cz..CC^ z..b sL ~C^zS Y^b@Cs zb - YC@LGS S' zPC \ b@CY- ^@ zPC @eP> ..PSp S' zPC \ - fS ~ \ @CzP bHzPC ^CszS'L S' zPC Lq ePi**

**K-zC..%R^zCqP Y%o**, PSCzPS<-zLbq%o.:s bqlS'-W%e-YC@-b^^G-zbqS'zCqP Y%4%o  
 [ C^@S'L>S P-s 4CC^ c^-\ C@HqzPC e~qpbsC bHzPS'..bqW-s - b^^G-zbq S  
 \ -S'Y%o^ Bd; QCYzC@zCq\ i , s zPC^-\ C s-LLGszs>S <b^z- S's \ Czfs cFYzC@  
 zb L-zC.:%e- ^@zPCq cFYzS^ zb G <P bzPCq a ^C\ Czfs S' zPS<-zLbq%o S zPC  
 b^^G-zbq \ S\ -zP>..PS-P \ G s-qS zPC^~\ 4Cq bHse YS Q- zC.:%e zP-z @b ^bz  
 P-fC- <bqCseb^@S' L UBS' Q- zC.:%o, ^bzPCqb^CS zPC; b^zpbYGb...; b\ eYzS%o  
 bq; G; >..PS-P <b^s@CqS zPC- YebssS4Y sz- zGs bHzPC \ b@CY- @CSL^Cq P-s zb  
 z-VCS'zb - <b^z>..PS-P S @CeC^@C^z b^ zPC^~\ 4Cq- ^@WS@s bHse YS S' zPC  
 \ b@CY

; %eS-S%R^@S- zGs zPC @LqC zb ..PS-P zPC \ b@CY S <%eS> S G <b^z- S's <%eS-  
 <b^szq<z s~P -s - Ybei [ C^@S' L eqpbsCs - \ Czfs <%eS-S%o..PS-P S zPC  
 q zS bH^b@CS S' - <%eC zb zPC zbz- Y^~\ 4Cq bH^b@CS S' zPC \ b@CY , ^bzPCq  
 \ Czfs ...s eqpbsC@S' qI:>..PS-P <b^zS zPC^~\ 4Cq bH%eCS S' szG @

; b^<-qC^<%oy PS<-zLbq%oS<Y@Cs \ Czfs zP-z zq%zb <ez-qC zPC^~\ 4Cq bH  
 e-zPs zP-z ^CC@zb 4Cs%~Pq^S C@ [ C^@S' L s-LLGszs @bS' L zPS 4%e~\ \ S' L  
 zPC b-z@LqC bH Yra p Q- ^@, ] ? Qe YS S' zPC \ b@CY..PSC bzPCq P-fC s-LQ  
 LGzC@ <b^zS' L zPC \ -zS ~\ ^~\ 4Cq bHe- q YCYe-zPs zP-z <^ 4C Cq C~zS' L  
 -z zPC s-\ C zS G-ebssS4Y% cFYzC@ zb zPC zbz- Y^~\ 4Cq bH^b@CS

[ bqCseG S<-W%e q { Yszs zPC HbYb..S' L \ Czfs si ,, PSC sb\ C \ Czfs \ SLPz @S Cq  
 Hq\ zPC b^Gs -s @C^C@S' zPC ..bqW4%qd C^@S' L>zPC HbYb..S' L @C^SS^ bHzPC  
 \ Czfs ..SY4C ~sC@S' zPS zPGSsi a ^C S ebqz ^z qG sb^ Hq zPC @S Cq^<Cs S zPC  
 ; GK ~sC@4% dXK>bH..PS-P zPC s \ C Hq \ C.bqWS ~sC@4% zPC ..bqWS' zPS zPGSs>  
 ..PS-P @bGs ^bz S<Y@C a p Q- zGs>sb zPC \ Czfs P-fC 4CC^ -@ ezC@zb qC Cz zPS>S'  
 zPC<-sGs ..PCq zPS \ -WGs - @S Cq^<G

yPC HbYb..S' L @C^SS^s -qC ~sC@S' zPC z-4Ys {i} -^@{i}

á K=dq<Gss \ b@CYLq eP

á ] =] b@Cs S' K

á y=, <zfsS S' K

á , =, qS bq<b^^G-zb^s S' K

á ; =K-zC.:%ef<b^^G-zbqsg S' K

á X=zPC sCz bH@szS' z<%eCS S' Ki Gbq G <P l L>Y {n N}>s~<P zP-z G <P  
 CC C^z S' X S - sCz <b^z- S' S' L <Cqz- S' ^b@Cs S' Ki

### 3.3 PLG - Process Log Generator

R' Q:>3~q zS' Cz -Y eqpbsC - Hq \ C.bqW Hq LC^Cq zS' L 4-sS' Css eqb<Gss \ b@CS  
 - ^@ zPCq Cq C~zS^ YLsi yPC Hq \ C.bqWS Cqe- ^C@S' Q:>..PS-P S' zpb@<Cs Ss



y- 4Y{i| = yPC" qsz P- YbHzPC \ Czfs @C ^C@S Q{:>..PSP - qzPC Hb<~s bHzPS  
 ..bqW rCC- Yb z- 4Y{i|i

; - zLbc%	[ Czfs	? C' ^Ssb^
rSC	] ~\ 4Cq bH ^b@Cs	$S_N(G) =  N  / yPC zbz- Y^{\sim} \setminus 4Cq bH^{\wedge} b@Cs$ $S' zPC Lq eP$
	] ~\ 4CqbH <SfQ SSS	$S_{act} =  T  / yPC \wedge \setminus 4Cq bH <SfSSS S' Ki$ $] bz @C' ^C@S' Q\{;i$
	] ~\ 4Cq bHL- zCQ ...%w	$S_C =  C  / yPC \wedge \setminus 4Cq bHL- zC..: %w S' Ki$ $] bz @C' ^C@S' Q\{;i$
	] ~\ 4Cq bH , ] ? Q- zC..: %w	$S_{and} =  C_{and}  / yPC \wedge \setminus 4Cq bH, ] ? Q$ $L- zC..: %w S' Ki ] bz @C' ^C@S' Q\{;i$
	] ~\ 4Cq bH † a p Q- zC..: %w	$S_{xor} =  C_{xor}  / yPC \wedge \setminus 4Cq bH \dagger a p Q$ $L- zC..: %w S' Ki ] bz @C' ^C@S' Q\{;i$
	? S \ CzCq	$diam(G) XC^{\wedge} LzP bHzPC Y^{\wedge} LCsz e- qz Hb \setminus$ $zPC sz- qz zb C^{\wedge} @^{\wedge} b@C bHK$
? C^sS%	? C^sS%	$(G) = \frac{ A }{ N  ( N -1)} yPC q zsb bHzPC \wedge \setminus Q$ $4Cq bH qsz zb zPC \setminus - \dagger S \setminus ebssSAC \wedge \setminus Q$ $4Cq bH qsz S' zPC \setminus b@CY$
	; bC <C^z bH <b^ ^C zSfS%	$CNC(G) = \frac{ A }{ N } yPC q zsb bH qsz zb ^b@Cs$ $S' zPC \setminus b@CY$
	, fCq LC @LqC bHb^ ^C zbzq	$d_C(G) = \frac{1}{ C } c C d(c) yPC- fCq LC b- zQ$ $@LqC bH L- zC..: %w$
	[ - †S ~\ @LqC bH <b^ Q ^C zbzq	$\hat{d}_C(G) = \max\{d(c)   c \in C\} yPC \setminus - \dagger S \setminus$ $b- zQ @LqC bH ^%L- zC..: %w$

sCb^ @S Cq zsb^ > dXK |i yPC S' Hbq \ zsb^ b^ zPC Hb \ C. bqW ecCsC' zC@S' zPS sC zsb^  
 S YqL C%w c fep@ < zsb^ bH S' Hbq \ zsb^ eqCsC' zC@S' zPC Sz. b.. bqW i yPC zCq \ dXK  
 ..SY4C ~sC@ zb qfCq zb 4bzP fCqSb^s bHzPC Hb \ C. bqW

yPC LC^ Cq zsb^ - YbqzP \ eqebsC@ S' zPS zPC Ss Ss - ^ C zC^ sB^ bHzPC dXK  
 eq<Gss LC^ Cq zsb^ Hb \ C. bqW - ^@zPC qHbqCP- s \ - ^%zPS Ls S <b \ \ b^ ..SP Si Gbq  
 zPS qf sb^ > zPC Hb \ C. bqW bH dXK ..SY4C qfCq @zb Hb \ ~C^ z%w ^@ - \ bqS' QzP  
 C f eY^ - zsb^ bHzPC Hb \ C. bqW ..SY4C eqfS@C@S' zPS sC zsb^ i

yPC LC^ Cq zsb^ C^LS^ C eqebsC@ 4% dXK ~sS - eqebsC@ <b^ zC zHCC Lq \ \ - q  
 f; GK g- s zPC 4- sS Hbq LC^ Cq zS^ L eq<Gss \ b@Cs> ..PCq- Yeq@ - S Y Ceq<Gss \ b@Cs  
 - qzPC qS- Y bHzPC eq@ < zsb^ q- Ys P bH dXK > . ^@ < ^ 4C qf eqCsC' zC@ - s - szqf L  
 bH Ss - Y P- 4Cz i yPC H Y @C' ^Ssb^ bHzPC <b^ zC zHCC Lq \ \ - q ..SY^ bz 4C sz- zC@  
 PCq > 4- z < ^ 4C Hb- ^@S' Q i Gs ~q {i eqfS@Cs - ^ C f - \ eY bH @Cqf- zsb^ zqC bH  
 zPC; GK > - Y^ L ..SP Ss szqf L - ^@ eq<Gss \ b@Cs> zC qz- zsb^ i

R^ Ss S eY C^ z- zsb^ bHzPC; GK > ..PSP Ss e- 4Y S %w f- SY 4Y > dXK @C' ^Cs - sCz bH  
 4- sS e- zCq^ s> bq eq@ < zsb^ q- Ys > zP- z- qf qf- qfS C%w ee Y C@ zb zPC eq<Gss \ b@CY  
 ..PSC zPC ..bqW bH B~q zS' @bCs ^bz C f eY S %w @C' ^C zPC S eqp@ < zsb^ e- zCq^ s> zPC %w

..SY4C @C ^C@S zPSs ..bqW sS <C Ss sS eYq zb qHq zb zPGsC eqp@-zsb^ e-zzCq^s  
 S'szG @bHzPC; GK ..PC @S~ssS'L zPC Hq \ C.bqW yPGsC 4 sS e-zzCq^s < ^ 4CsCC^  
 S "L-qC {iJi

r b\ C bHzPC 4 sS e-zzCq^s bH" L-qC {iJ <b^z-S' - ^ CC\ C^z < YC@ pemptyi yPSs  
 CC\ C^z < ^ 4CzPb-LPz bH s zPCD ~Sf- YC^z bH ^b^QCq\ S'- Ys%o 4bYS' zPC; GK >- ^@  
 <- ^ 4C qCeY <C@ 4%o ^%bHzPC bzPCq 4 sS e-zzCq^s>S' <Y@S'L zPC <b^z-S' S'L e-zzCq^  
 SsOHi Gbq zPSs qC sb^>zPSs CC\ C^z ..SY4C qHqC@ zb -s - eY<CPbY@Cq bHzPC bzPCq  
 e-zzCq^si rS' <C Ss zPCD ~Sf- YC^z bH ^b^QCq\ S'- Ys%o 4bY- Y" ^sPC@ LC^Cq zC@  
 eqp<Css \ b@C\ <b^z-S' ^b s~<P eY<CPbY@Cqi

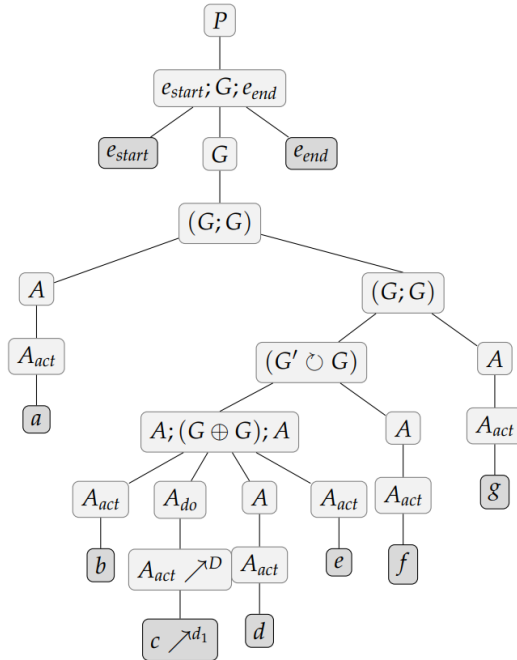
yPCLC^Cq zsb^ Hq \ C.bqW bH XK - Yb..s zPC~sCq zb seC-S%o. CSLPzs HbqG <P bHzPC  
 eqp@-zsb^ q-Ys S' "L-qC {iJi yPCLC^Cq zsb^ bH eqp<Css \ b@Cysz- qS 4%o@C ^S'L  
 - sz-qz - ^@C^C^C^z>s~<P zP-z zPC S'SS Y\ b@CYSs @C ^C@ 4%oPC szsP L ne\_start t  
 Pempty t e\_endni yPC^>zPC qsz bHzPC \ b@CYSs LC^Cq zC@ 4%oqC~qSfY%o qCeY <S'L zPC  
 eY<CPbY@Cq pempty ..SP b^C bHzPC 4 sS e-zzCq^s>..PS-P zPC^ qCeY <Cs - YbHSs b..^  
 eY<CPbY@Cq ..SP bzPCq 4 sS e-zzCq^s> ^@sb b^>~^zSYzPCqC- qC^b \ bCqCeY <CPbY@Cq  
 YH S' zPC \ b@C\ bq~^zSY- seC-S C@ \ - †S - \ Ys S b^ zPCs S bHzPC eqp<Css \ b@C  
 Ss qC <PC@ „ P-z e-zzCq^s - qC <PbsC^ zb qCeY <C G <P eY<CPbY@Cq Ss 4 sC@ b^ zPC  
 ..CSLPzs - ssL^C@ zb G <P bHzPC e-zzCq^s - z zPC 4CLs^S'L bHzPC LC^Cq zsb^>..PS-P  
 zq ^sYzCs S' zb zPC eqp4 4SSsCs bH<PbbsS'L G <P e-zzCq^i yPGsC eqp4 4SSsCs sz-%  
 zPCs- \ CzPq-LPb-z zPCLC^Cq zsb^ bHG <P eqp<Css \ b@C

yPC C^zC^sSb^ eqpebsC@ 4%oPSs zPGsS \ -S'Y%o ' Czs zPC <b^zS' ~b~s qC- Y~Y zsb^  
 bHzPC eqp4 4SSsCs Hbq <PbbsS'L G <P e-zzCq^ Hbq G <P ^C.. e-zzCq^ zP-z Ss <PbsC^>  
 - ^@ -s s~<P sP- qCs \ bsz bHzPC qsz bHzPC Hq \ C.bqW..SP dXKi yPCqHqC> zPC  
 <b\ \ b^ - YSSs bHzPC dXK - ^@zPC C^zC^sSb^ eqpebsC@ S' zPSs zPGsS ..SY4C qHqC@  
 zb -s zPC Hq \ C.bqW bHzPC eqpebsC@ - YbqSP\ i Gbq C^ - \ eY>zPC 4 sS e-zzCq^s - ^@  
 ...%bHqC~qSfY%o LC^Cq zS'L zPC - YbqSP\ Ss e-qz bHzPC Hq \ C.bqW

yPCLq \ \ - q~sC@ 4%oPC Hq \ C.bqW b^Y%P- s - Ys S C@ C^eqCssSfC^Css S' zCq\ s  
 bHzPC ebssSYC 4-sS Css eqp<CssCs Ss < ^ eqp@<C> - ^@ Ys Ss zPC Hq \ C.bqW zb b^Y%o  
 eqp@<S'L 4Y<Vqzq<z-qC@ eqp<CssCs>- zCq\ ..PS-P Ss HqPCq C^eY S' C@ S' 9v:i 3CQ  
 <~sC bHzPSs> zPC eqp<CssCs eqp@<C@ 4%oPC Hq \ C.bqW..SY- Y4C sb- ^@ eqp<CssCs>  
 ..PS-P Hbq C^ - \ eY\ G ^s Ss @bGs ^bz <b^z-S' - ^%oC @Y<Vsi yPSs sb- ^@ Css Y @s zb  
 zPC Hq \ C.bqW4CS'L ~^- 4Y zb eqp@<C \ b@C\ <b^z-S' S'L - ^%b4fS~s • b..qCY zC@  
 CqfPq zP-z < ^ 4C @CzCzC@ ..SPb-z @b\ - S' Wb..Y@LCQ Di

y- 4Y {i} = yPC \ Czfs @C ^C@S' q{:} ..PS-P - qC zPC Hk~s bHzPS ..bqW rCC - Yb  
z- 4Y {i|i

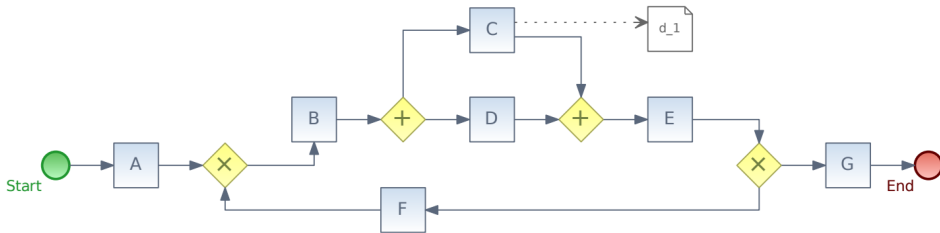
; - zCbq%	Czfs	? C' ^SS^
d- qSS^ - 4SS%	rCe- q 4SS%	$(G) = \frac{\{n N/n\} \{zCqC\}}{ N -2} yPC q zS bH$ $\leftarrow zCqCzS z b zPC ^\sim \ 4Cq bH^b@Csi$ $\leftarrow zCqCzS s - fCqCzP-z <q zCs \setminus bC$ $sCe- q zC@<b\ eb^C^zs S' - Lq eP ..PC^ qCQ$ $\setminus bfC@$
	rC ~C^zS Y%	$(G) = \frac{ A  (T \times T)}{ A } yPC q zS bH- qs 4CQ$ $z..CC^ ^b^Q- zC.. %\delta b@Cs z b - Y- qs$
	r zq- z- qC@^C ss	$N = 1 - \frac{S_N(G')}{S_N(G)} yPC q zS bH^b@Cs S' -$ $s-4Lq eP K' z b zPC ^b@Cs S' K > ..PCq K$ $S b4z- S' C@ 4% ee YSL - sCz bHq@- zS^$ $q- Ys @C ^C@S' q{:} - s \setminus - ^\%zS Cs - s ebsSQ$ $4Yi yPCq@- zS^ q- Ys q@- Cs szq- z- qC@$ $4Yb<W bH Lq ePi$
	? Ce zP	$(G) = \max\{ (n)/n \ N\} yPC \setminus - \dagger S \setminus$ $@Ce zP bH- Y^b@Cs > ..PCq zPC @Ce zP bH-$ $s' LY^b@Cs zPC ^\sim \ 4Cq bH e YQ- zC.. %$ $zP- z P- fC z b 4C fSSC@S' bq@Cq z b q- <P S$ $H\ zPC sz- q ^b@G$
; b^^Czbq S' zCq; eY%	; b^^Czbq \ SQ \ - z-P	$MM(G) = MM_{xor} + MM_{and} yPC ^\sim \ 4Cq$ $bHL- zC.. %se Ys zP- z - qC ^bz \setminus - zPC@ z b$ $- L- zC.. %bS i$
	; b^^Czbq PCQ CpLC^C%	$CH(G) = - \frac{1}{\{and, xor\}} p(l) \log_2(p(l)) >$ $..PCq p(l) = \frac{ C_l }{ C } yPC C^z p e % b fCq @S CqQ$ $C^z L- zC.. %z @Csi$
	; b^z qY • b... <b\ eYiS%	$CFC(G) = \frac{1}{2^{d_{out}(c_{xor})} + 2^{d_{out}(c_{and})} - 1}$ $+ \frac{c_{xor} d_{out}(c_{xor}) + c_{and} d_{out}(c_{and})}{2^{d_{out}(c_{xor})} + 2^{d_{out}(c_{and})} - 1}$ $? C' ^C@S' q: - s - \setminus G s- qC bH<b\ eYiS%$ $S' zCq\ s bHPb... \setminus - ^\%sz zCs bHCiC~zS^$ $zPC @CsL^Cq bH- eq<C ss P- s z b VCe S'$ $\setminus S@$
; %SS%	] ~\ 4Cq bH <Q <Ys	$CYC_N =  L  / rz- zCs zPC ^\sim \ 4Cq bH e Ss^ <$ $<%Ys S' Ki yPs S' ^bz - \setminus Czfs @C ^C@S'$ $q{:} - s bzPCq \setminus Czfs > 4- z S q zPCq @C ^C@$ $4% j SsC^ S' qI: i$
; b^<- qC^ <%	ybV se Yz	$TS(G) = \frac{c_{Cor} C_{and} d_{out}(n) - 1}{2^{d_{out}(n)} - 1} yPC$ $b- ze- zCqC bH, ] ? Qs S' - ^@ a p Qs S'$ $\setminus S' - s b^G$



f-g, ^ C\_t-\ eYbH @Csf-zb^ zqC Hb\ zPC; GK bHdXK

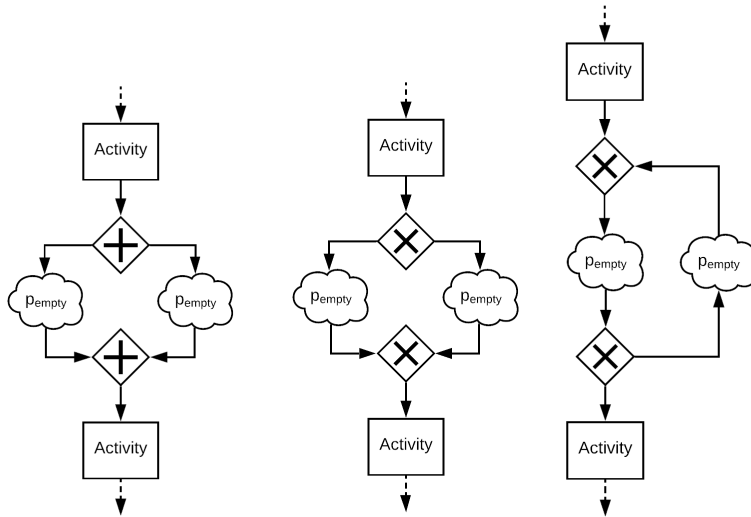
$e_{start}; (a; ((b; (c \xrightarrow{d_1} \oplus d); e \circ f); g)); e_{end}$

f4gyPCszp^L @Csf@ Hb\ {i{f-g

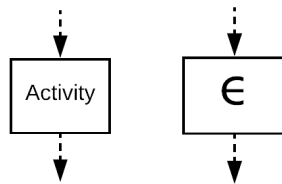


f<gyPC3d[ ] qeCqS^z-zb^ bH{i{f-g

GSL~qC {i{ =, ^ C\_t-\ eYbH epc<Ss \ b@CYedp@-<@ 4%zPC; GK bHdXKi pCedpQ @-<@ Hb\ 9:i

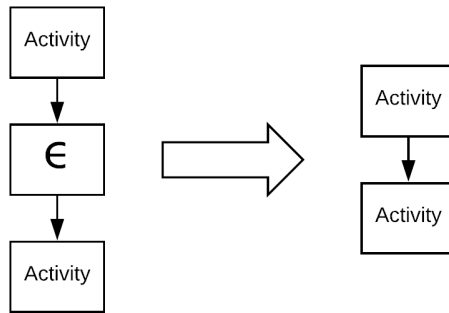


f-g Parallel execution e-zQf4g Mutual exclusion e-zQ f<g Loop e-zzQq'



f@g Activity e-zQfCg Skip e-zzQq'

GSL~qC { iJ= yPC4 sS< e-zzQq's>bqeqp@<Sb^ q Ys>bHdXK>..PSP-qC@GqfC@Hp\ Ss ; GK i yPC S'zCqCz-zS^ bHzPC sVte e-zzQq' <- ^ 4C sCC^ S^ "L~qC {il i



$\text{GS} \sim \text{qC} \{ \text{il} = \text{yPC} \text{S}^{\wedge} \text{zC} \text{p} \text{q} \text{z} \text{z} \text{b}^{\wedge} \text{bHzPC} \text{sV} \text{e} \text{-} \text{z} \text{z} \text{C} \text{q}^{\wedge} \text{bH} \{ \text{iJfG} \} \text{R} \text{s} \text{D} \sim \text{Sf} \text{-} \text{Y}^{\wedge} \text{z} \text{sz} \text{q} \text{L}$   
 $\text{q} \text{e} \text{q} \text{s} \text{C}^{\wedge} \text{z} \text{z} \text{b}^{\wedge} \text{..b} \text{-} \text{Y} \text{@} \text{4C} \text{n} \text{A}_{act} \text{t} \text{t} \text{A}_{act} \text{n} \text{n} \text{A}_{act} \text{t} \text{A}_{act} \text{ni}$

# CHAPTER 4

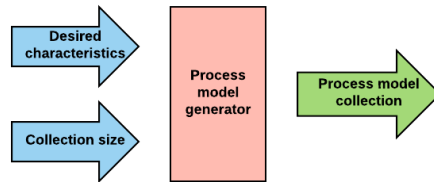
## Process Model Generation Algorithm

„ PC^ <b^szq->S^L - 4C^<P^> - qWbHeq<Gss \ b@C^> zPC @Gsq@ epeGqzSs bHzPC \ b@C^ < ^ f- q%4- sC@b^ zPC- YlbqzP^ 4CS^L 4C^<P^> - qW@- ^@zPCe- qbsC bHzPC 4C^<P^> - qW yPS \ G ^s zP- z e- zS^L qS G q-PCq S^ @sq-z <b^zqYbH.L- P- z epeGqzSs zPC LC^Gq zC@ eq<Gss \ b@CY<bYC-zb^>s ..SY- fC S S ebqz- ^zi yPS S ..P%@b^S^L zPS>S^ zPC Hq\ bHzPC \ Czq-s bHzPC eq<Gss \ b@CY<bYC-zb^>S zPC \ -S^ H<-s bH zPS ..bqW Ob..CfGq-zPS ..bqW..SY- Ysb- ss-\ CzP- z>S^ LC^Gq Y- Lbb@4C^<P^> - qMS @/CqG-SG zP- z Ss <P- q <CqszSs - q @/CqG HqzPbsC zP- z - q^bz @sq-zY%seG-S C@ 4%zPC qS G q-PCq y PC YLS 4CS^@zPS S zP- z ..PSC- LC^Gq zS^ - YlbqzP^ sPb- Y@ C^s-q zP- z zPC eq<Gss \ b@C^ P- fCzPC seG-S C@<P- q <CqszSs>S sPb- Y@- Ysb zq%zb \ - Ws-q zP- z zPC 4C^<P^> - qWb/Cq- s \ - ^%e- sG- s ebssSYC-sb zPC 4C^<P^> - qWP- s - ^ S^<q sC@<P- ^<CbHbf/Cq^L- Y<- sG zPC- YlbqzP^ ..SY- fCz b@G Y..SP S^ qG YH R^ <b^zS^-- zS^ bHzPS>S ..SY- Ysb 4C- ss-\ C@zP- z- Lbb@4C^<P^> - qMS qG Ysz>SG <b^z- S^s - qG Ysz<- <bYC-zb^> bHeq<Gss \ b@C^>- ^@zPC \ b@CYLC^Gq zS^ - YlbqzP^ sPb- Y@- Ysb zq%zb H<Ssz- zC zPSi

y PC \ - S^ @G bHzPC LC^Gq zS^ - YlbqzP^ S zP- z S^sz @ bHseC-S%L zPC eq4Q - 4SSS bHG <P ebssSYC e- zCq^ zb LC^Gq zC> - s S zPC < sC Hq C^S zS^L LC^Gq zS^ - YlbqzP^ s>~sCq seG-S%zPC <P- q <CqszSs zPC%.. ^z zPCq eq<Gss \ b@CY<bYC-zb^> zb C^PSi y PC- YlbqzP^ zqG zb - <PSCzPCsC <P- q <CqszSs 4%@%> \ S- Y%ssL^Q S^L - ^@q ssL^S^L zPC eq4- 4SS%bHG <P e- zCq^ - z q-^Q S^ G-4- sC@b^ zPC <-qq^z - ^@Gsq@sz- zCbHzPC \ b@CY yPS sCzS^ C^eY S^s zPC- YlbqzP^ S^ HqPCq @Cz- S^ bH. PS-P - esC-@q@C @Cs-qe zS^ <- ^ 4C sC^ S^ - YlbqzP^ c zPq-LP D

] bzC zP- z zPC- YlbqzP^ epebsC@S^ zPS ..bqWb^Y%@G Y ..SP zPC LC^Gq zS^ bH zPCszq-<z-q YeqeGqzSs bHeq<Gss \ b@C^ yPS \ G ^s zP- z S^ @bG^ bz <b^<Cq^ SsOH ..SP zPC^> \ Gs bHb^ eb^C^z>bqzPC eq@<zS^ bq <b^s^> ezS^ bH@z- b4U<zS>- s S zPC <- sC ..SP zPC dXK Hq \ C.bqW Rz b^Y%b^<Cq^s SsOH..SP zPC LC^Gq zS^ bH \ b@C^ bH4- sS ..bqWb...e- zCq^si

y PC <P- q <CqszSs zP- z zPC- YlbqzP^ z- Ws - s S^e-z Hq \ zPC ~sCq- s@Cs Hq \ zPC sS C bHzPC <bYC-zb^>- qe- esC@- s e- S^ bH- \ Czq- ^@zPC @szP4-zS^ bH Ss z- qCz f- YCsi B- <P e- Sq seG-S Gs - <P- q <CqszSs bHzPC <bYC-zb^> bHLC^Gq zC@ eq<Gss \ b@C^>- ^@ ..SY 4C qHq@ zb - s zPC b4Y- zS^ Hq zP- z \ Czqsi , s s-<P>



**GS~cQ Jic= y PC S'e~zs - ^@b~ze~zs bHzPCLC^Cq zsb^ - YbqfP\ i**

G <P b4YL zsb^ S - e SjbH \ Czqf - ^@ - seC-S < @Szqf4-zsb^ f..SP - seC-S C@ \ G ^>  
 f - qf ^ <C> Cz ig r S^C zPC b4YL zsb^ seC-S S zPC @CSqC @Szqf4-zsb^ bHC <P \ Czqf >  
 zPS \ G ^s zP - z zPC \ Czqf s bHzPC ..PbYC eq<Css \ b@CY <bYC zsb^ ..SYHbYb... zPS  
 eq4 4SS% @Szqf4-zsb^ i yPC @Szqf4-zsb^ bHzPCLC^Cq zC@ <bYC zsb^ S @S<-ssC@ S  
 HzqPCq @CzP S' sC zsb^ Ji|i

„ PSC zPC - YbqfP\ z Vb - s S'e-z - \ Czqf - ^@ zPC @Szqf4-zsb^ bHSz z qLz  
 f - YCs >C <P eq<Css \ b@CY S LC^Cq zC@ Hb \ - s S' LC z qLz f YC ..PS P S b4z - S C@  
 Hb \ zPC seC-S C@ @Szqf4-zsb^ i yPS f - YC @Sz - zCs zPC f - YC zP - z zPC seC-S < eq<Css  
 \ b@CYPb ~Y@ 4CLC^Cq zC@ ..SPi B - <P bHzPC f - YCs - qL C^Cq zC@ - z zPC 4LS^S'L  
 bHzPCLC^Cq zsb^ bHzPC eq<Css \ b@CY 4 - sC@ b^ zPC b4YL zsb^ - ^@ zPC seC-S C@  
 @Szqf4-zsb^ > S' Y' C I S' - YbqfP\ |i yPC e - SjbH \ Czqf - ^@ Ss z - qLz f - YC S  
 sS eY% qCf qC@ z b - s - z qLz Hbq zPC eq<Css \ b@CY

y PCLC^Cq zsb^ - YbqfP\ Hbq C <P eq<Css S'sz ^ <C S 4 - sC@ b^ zPC Hq \ C. bqWbH  
 dXK > ..PS P P - s 4CC C eY S' C@ S' sC zsb^ {i|i yPS \ G ^s zP - z U - sz - s dXK > zPC  
 - YbqfP\ LC^Cq zCs G <P eq<Css \ b@CY 4% qC - qf C% LC^Cq zS'L ^C...e - zzCq^s 4 - sC@  
 b^ zPC; GK > ~ ^ zY^b \ bqC e - zzCq^s < ^ 4CLC^Cq zC@ , z G <P qC - qf C LC^Cq zsb^ >  
 zPC - YbqfP\ @C - S@Cs ..PS P ^C...e - zzCq^ bq <b \ eb^ C^z zb LC^Cq zC > 4 - sC@ b^ zPC  
 ..CSPz zP - z S - ssL^C@ zb G <Pi Ob..CfCq ..PSC zPC LC^Cq zbq bHdXK - ssL^s zPC  
 ..CSPz Hbq C <P e - zzCq^ - z zPC 4LS^S'L bHzPC eq<Css LC^Cq zsb^ > - Hq ..PS P zPC %  
 q \ - S' ~ ^ <P - ^ LC@ Hbq zPC qsz bHzPCLC^Cq zsb^ > zPC - YbqfP\ eqebsC@ 4% zPS ..bqW  
 @% \ S - Y% ssL^s ^C....CSPz zb G <P e - zzCq^ - z G <P qC - qf C S Cq zsb^ i

y PC...%zPC..CSPz - qC @Szqf4-zC@ S @C - S@C@ 4% zPC <- qf C^z sz - zCbHzPCLC^Cq zC@  
 \ b@CY SG ..P - z zPC \ b@CY <- qf C^z % YbW YW > - s ..CY - s ..P - z zPC \ b@CY s - ebsC@  
 zb YbW YW > SG Ss \ Czqf - z qLz f - YCsi yPS \ G ^s zP - z - z G <P qC - qf C LC^Cq zsb^  
 szCe > zPC eqLq \ YbW - z zPC \ Czqf s bHzPC <- qf C^z % LC^Cq zC@ \ b@CY - ^ <b \ e - qf s  
 zPS zb zPC z - qLz f - YC 3 - sC@ b^ zPC @S Cq^ <C > zPC - YbqfP\ @C - S@Cs zb ..PS P @C qC  
 zPC LC^Cq zsb^ bH <Cq S' e - zzCq^ S 4C^C <S Y - ^@ - ssL^s - ..CSPz zb zPC e - zzCq^  
 - <bq@S LY% yPC C - z eq<C@ - qC Hbq - ssL^S'L ..CSPz zb G <P e - zzCq^ > - ^@ ..P - z  
 \ - Vb S 4C^C <S Y S - 4S \ bqC <b \ eY C zP - ^ zPS > - ^@ S @S<-ssC@ S' HzqPCq @Cz - SY  
 S' sC zsb^ Ji|i



:YS Tc3n0RA,R03 /3c,aCUjCRN

H;Q`BiRK7b`Qm3?2b+`B#2 i?2 ;2M2` iBQM H;Q`Bi?K T`QTQb2/  
i2`Kb Q7 Tb2m/Q@+Q/2X h?2 rQ`FBM;b Q7 i?2 H;Q`Bi?K Bb i?  
2Hb2r?2`2 BM i?2 i?2bBb- #mi Bb K2 Mi #Qi? b KQ`2 T`2+Bb  
Q7 BiX :h1L1\_ h1@S\_P\*1a7@MFjBQM b?QmH/ #2 +QMbB/2`2/ i  
BMi2`7 +2 iQ i?2 H;Q`Bi?K- bm+? i? i Bi i F2b BMTmib b /2b-  
M/ T`Q/m+2b M QmiTmi BM ++Q`/ M+2 rBi? i?2 7mM+iBQMöb  
BM };m9XR h?2 7` K2rQ`F Q7 i?2 ;2M2` iBQM 2M;BM2 Q7 SG: -  
b H;Q`BR?KBM/j- r?B+? `2 H `;2Hv 2[mBp H2MiX h?2`2 `2?  
/Bz2`2M+2b- i?2 KQbi bB;MBp+QMi#2B)BjB) B)B)2TH +2?QH/2  
Empty BM i?2 T`2Mi T ii2`M- BX2X i?2 T ii2`Mi? i Bb iQ #2`2T  
T ii2`M- Bb`2TH +2/ #vi?2 +?Qb2M T ii2`M rBi? TH +2?QH/2`b  
i?2Kb2Hp2bX h?2`2 bQM 7Q` i?Bb /Bz2`2M+2XbBmQb+2m bb2/  
KBMQ` /Bz2`2M+2B7b B)MCHBM?22`2 i?2 i` ;2i p Hm2 7Q` 2 +? K2  
/2i2`KBM2/- b r2HH bi?2 T` K2i2`b M/`2im`M@p Hm2b Q7  
i?2 2z2+ib Q7 i?2 H ii2`- KBMQ` /Bz2`2M+2Sh12M)K)B)M #27Q  
Bb r?2`2 i?2 K2i`B+ i` ;2i p Hm2b `2 mb2/X h?Bb K2 Mb i? i  
#2ir22M i?2 7` K2rQ`Fb + M\*#2S7Qm@Q1BAM/h Bb BM ++Q`/ M+  
rBi? i?2 K BM +QMi`B#miBQMb 7`QK i?Bb rQ`F #2BM; i?2 r vi?  
T ii2`M `2/vM KB+ HHv /2i2`KBM2/ i2 +? Bi2` iBQM # b2/ QM  
bi i2 Q7 i?2 KQ/2HX b bm+?- HH Qi?2` T`ib Q7 i?2 H;Q`Bi?K  
rBi?BM i?Bb 7mM+iBQM rBHH Q7 72MK#22Q7 2?22/H;Q`Bi?K- bBM  
Bi b? `2b i?Bb rBi? SG:X  
h?2 Tb2m/Q@+Q/2 H `;2Hv 7QHHRb i?B+Q7Q`2MiBQMöb Q7 M  
i? i Q#D2+ib T bb2/ b `;mK2Mib- BM+Hm/BM; ``vb- `2 T bb  
/2pB iBQMb 7`QK i?2 +QMp2MiBQM- b r2HH b Qi?2` +QMp2Mi

Ç bbB;MK2Mib iQ p `B #H2b `2b2mF`2bb2/BMbi2x≠QX

Ç ai`BM;b `2/2b+`B#2/ BM D p @HBF2bvMi t-r?2`27Q` 2t  
rQmH/ T`Q/m+2 i?2 bi`BM; ô>2HHQqQ`H/ôX

Ç Empty Bb `2; `/2/ b M Q#D2+iX h?Bb K2 pMbi@Q#TD)B)BM;  
BM1L1\_ h1@S Thhb1b i?2 +Q`2bTQM/BM; Q#D2+i- MQi bB  
bi`BM;

Ç h?2 T ii2`Mb BM i?2 Tb2m/Q2P+Q2M2HBM72 H;Q`Bi?K b  
/2}M2/ b BMjXn`2

Ç \*2`i BM7mM+iBQMb + HH2/ `2 MQi7Q`K HHv/2b+`B#2/ b  
rQ`FBM;b `2 MQi 2bb2MiB H iQ i?2 +QMi`B#miBQMb Q7 i?  
[m2biBQM `2 b 7QHHRbX

+?QQb2S ji?2 Q)Qb2b T ii2`M # b2/ QMi?2 r2B;?ib bbB;  
h?2 T`Q# #BHBiv Q7 +?QQbBM; 2 +? T ii2`M Bb i?2 r2

T ii2`M- /BpB/2/ #v i?2 iQi HpMmK#2` Q7 r2B;?ib Q7 HH T  
 rQ`/b- i?2 T`Q# #Prbb) v Q/7p)= p2P W(p)- r?2p2P M/  
 W `2 b /2}M2/ B M M B B Mbi?2 +Q/2X  
 ` M/QKJ77Q Qb2b ` M/QK MmK#2` # b2/ QM bT2+B}2/ /I  
 f - b /2}M2/ B M M B B M2Q` B i ? K Bb + QmH/ #2 Mv /Bbi`B#miBQ  
 Bb BMi2M/2/ iQ #2 QM2 i? i`2~2+ib `2 HBbiB+ /Bbi`B#m  
 K2i`B+- b /Bb+mbb2 X B M C b 2 i ? B T Q M T Q b 2 b Q 7 i ? B b r Q ` F - S  
 /Bbi`B#miBQM ? b #22M +?Qb2M- r?B+? K2 Mb i? i i?2 7  
 ` M/QK p Hm2 7QHHRBM; SQBbbQM /Bbi`B#miBQM rBi  
 p Hm2- i?2 BKTH2K2Mi iBQM Q7 r?B+8 B X / B b + m b b 2 / B M b  
 `2KQp2SH +2? Q, H i 2 B b U B b K 2 i ? Q / 7 Q ` ` 2 K Q p B M ; i ? 2 T H +  
 Pempty i? i 2tBbi BM i?2 T`Qg+2b b ? B C b / 2 H 2 K 2 7 Q ` / Q B M ; b Q B  
 2tTH BM2/ B M X p X + B Q M 2 i ? Q / ` 2 i m ` M b i ? 2 ` 2 b m H i B M ; K Q / :  
 BbG `;2`h? M `2 P 7 r p Q, K 7 Q B b U K 2 i ? Q / i 2 i m B M i ? 2 M m K @  
 #2` Q7 TH +2?QH/2`b BM i?2 ;2M2p B B / B T ? Q + M b i ? K Q / 2 H  
 H `;2bi p Hm2 BM i?2 ` M;2 Q7 p H m 2 Q 7 / 2 ) M 7 2 Q b i i ? 2  
 BM b2 + B X M  
 BbaK HH2`h? M `2 P 7 V, Q K ? B C K 2 i ? Q / i 2 i m B M i ? 2 M m K @  
 #2` Q7 TH +2?QH/2`b BM i?2 ;2M2p B B / Q T ? Q + M b i ? K Q / 2 H  
 H Q r 2 b i p H m 2 B M i ? 2 ` M ; 2 Q 7 p H m 2 Q 7 / 2 Q M 2 Q B M ?  
 b2+i B X M j  
 `2 +?2/h `m2iUV, h?Bb 7mM+iBQM +QKT `2bmi Q27+m``2Mi p  
 K2i`B+ iQ Bib i `t Xi p ? B M 2 + Q K T ` B M ; e B K B ; B M Q / m + 2 / -  
 bm+? i? i i?2 7mM+iBQM `2im`Mbi e 2 # Q Q + 2 M ? B H m 2 Q 7  
 2``Q` K e; B N # 2 2 M b 2 i i Q X 8 W Q 7

:YI TaR\$ \$CICjw /CcjaC\$njCRN R8 j@3 K3jaC,

q?BH2 Bi Bb /B{+mHi iQ /2}M2 i?2 +? ` +i2`B2iHB T i B 7 2 B bi +QM b  
 KQ/2Hb- Q`r? i T`Q+2bb KQ/2Hb `2b2K#H2`2 H@HB72 QM2b- Bi  
 #Qmi i?2 T`Q# #BHBiv /Bbi`B#miBQM Q7 `2 H T`Q+2bb KQ/2H  
 J2M/HBMj;)BM (Hvx2b 7Qm``2 H@HB72 +QHH2+iBQM b Q7 T`Q+2bb  
 Q7 K2i`B+b M/i?2 K2 M M/p `B M+2 Q7 i?2 B`T`Q# #BHBiv /Bbi`  
 i?Bb rQ`F- r2 + M b22 i? i 2p2M i?Qm;? 2 +? K2i`B+ ? b p `vBM; H  
 2 +? p `B M 2 - 2 M / i ? 2 K 2 M M / p ` B M + 2 i 2 M / i Q 7 H H r B i ? B M 7 +  
 Qi?2`X q?BH2 MQi +QM +HmbBp2- i?Bb BM/B+ i2b i? i +QHH2+iBQ  
 iQ 7QHHR MQM@mMB7Q`K T`Q# #BHBiv /Bbi`B#miBQM 7mM+  
 (9y- r?2`2 i?2 /Bbi`B#miBQM Q7 i?2 H2M; i? Q7 i?2 HQM; 2bi T i? 7C  
 /BbTH v2/ b ?BbiQ; ` Kr?B+? +H2 `Hv BM/B+ i2b +m`p2/- : mb  
 Ai Bb ?Qr2p2` /B{+mHi iQ b v Mvi?BM; /2}MBi2 #Qmi i?2 FBM  
 i`B#miBQM 7mM+iBQM `2 H T`Q+2bb KQ/2H +QHH2+iBQM b i2M/ i

H;Q`Bi?K1L1\_ h1@S\_P\*1aa@JP.1Ga

BMTmib,  
R,O f (m;f)jm 2 M;f 2 Fg . h?2 Q#HB; iBQM b Q7 i?2 H;Q`Bi?K-  
O(m) = d B b i?2 T`Q# #BHBiv / Bbi`B#miBQM 7Q`  
k,s2 N . h?2 bBx2 Q7 i?2 ;2M2` i2/ +QH

;HQ# HHv /2}M2/ +QMbi Mib,  
j, F . HH TQbbB#H2 T`Q# #BHBiv /Bb  
9,P . HH TQbbB#H2 T ii2`M  
8,M : bi`BMR . HH TQbbB#H2 K2i`B  
e,M<sup>0</sup> f mj(m;f) 2 Og . i?2 b2i Q7 K2i`B+b T bb2/ b Q#HB; i

d,7mM+iBQM\_ h1@S\_P\*1aa@JP.1GsaV  
3, G . i?2 +QHH2+iBQM Q7 ;2M2` i2/ T`Q+  
N, 7QR iQ/Q  
Ry, G G[f :1L1\_ h1@S\_P\*1aa@JP(O)G  
RR, 2M/ 7Q`  
Rk, `2im`M  
Rj,2M/ 7mM+iBQM

H;Q`Bi?K1L1\_ h1@S\_P\*1aa@JP.1G

BMTmib, . :HQ# H p `B #H2b /2}M2RBH HbQ`Bi?KbbB#H2 ?  
R,O . h?2 b2i Q7 Q#HB; iBQM b- b /2}M2/ BM

k,7mM+iBQM\_ h1@S\_P\*1aa@JP.1G  
j, T:M! R. h?2 K2i`B+ i `;2i p Hm2(m)b Bb+ ??i2`ii`;2i p Hm2 Q7  
m  
9, 7Q` nH2M<sup>0</sup> /Q  
8, T(m) ` M/Q(O(m))  
e, 2M/ 7Q`  
d, g "e\_start c ô Y\_empty Y ô e\_end ô . i?2 ;2M2` i2/ T`Q+2bb KQ/  
3, `2TH p 2 g rBi?1L1\_ h1@S hh1\_(I;g;P\_empty )  
N, `2im`M  
Ry,2M/ 7mM+iBQM

M HvbBb Q7 i?2b2 +QHH2+iBQM bX AM Q`/2` iQ #2 b ;2M2` H  
iQ +?B2p2 +HQb2M2bb iQ`2 HT`Q+2bb KQ/2H +QHH2+iBQM  
TQb2/ #v i?Bb rQ`F b mTTQ`iM v B MQ#` B B H B i v H / B - b i ` B # Q n i B Q M 7 m i  
K2i`B+b Q7 i?2 ;2M2` i2/ +QHH2+iBQM X Ai Bb ?Qr2p2` rQ`i?  
K2Mi iBQM Q7 i?2 H;Q`Bi?K iQ b mTTQ`i +2`i BM T`Q# #BHB  
MmK#2` ;2M2` iQ` b b T B - Q B } 2H ; B M B B K 2 [ m B ` 2 / X

H;Q`Bi?KjL1\_ h1@S hh1\_L

BMTmib, . :HQ# Hp `B #H2b /2}M2RB HbQ`Bi?KbbB#H2 ?2  
R,T . h?2 b2i Q7 K2i`B+b M/i `;2i p Hm2pQ7b /2;QMB/BM HBM2  
k,g . h?2 +m`2MiHv ;2M2` i2/ T`Q+2bb K  
j, Plocation 2 g . h?2 TH +2?QH/2` T ii2`M i? i Bb iQ #2`2

9, 7mM+iBQM\_ h1@S hh1\_ -g-Plocation V . \_2+m`bBp2Hv ;2M2` i2b  
T ii2`M BM T Plocation-2 67

8, W \*PJSih1@q1A:>h(A;g;Plocation )

e, Pchosen +?QQb2S i(W)M

d, `2TH p,2 BMrBiPchosen

3, 7Q` PEmpty 2 Pchosen /Q

N, `2TH PEmpty rBi?1L1\_ h1@S hh1\_ -g-Pempty V

Ry, 2M/7Q`

RR, `2im`Pchosen

Rk,2M/7mM+iBQM

:Yk r3C<@CN<T jj3aNc

h?2 r2B;?BM; Q7 T ii2`Mb- Q` +QKTmiBM; fP2B1hr2@;q1A:-Bba/QM  
i HBMBM i?2 Tb2m/Q@+Q/2X h?2 K BM B/2 Q7 bbB;MBM; r2B;?  
+QMi`B#mi2b rBi? +2`i BM p Hm2 iQ 2 +? T ii2`Möb r2B;?i- /2T  
Q7 T`Q/m+BM; i?2 T ii2`M BM `2H iBQM iQ i?2 K2i`B+ BM [m2b  
i?2 }M H r2B;?i Q7 2 +? T ii2`M Bb i?2 bmK Q7 i?2 r2B;?ib T`QpB  
b M 2t KTH2- +QMbB/2` ;2M2` iBQM BMbi M +2mrB#2`QQ72 i `;2i  
+iBpBiB/b MQi?2Mn7Q#2` Q7 ;Xi2q?2BM + H+mH iBM; i?2 r2B;?i 7C  
b2[m2M+2 T ii2`M- Bi KB;?i `2+2Bp2b r2B;?i 7`Q0:5X2 MmK#2`  
q?2M Bi i?2M `2+2Bp2b -0:5M7` Q#mi?2QMnQ#2` Q7 ; i2r vb- i?Bb r  
// mTiQ iQi Hr2B;?i2Q70:75X

h?2 iQi H+QMi`B#miBQM Q7 r2B;?ib 7`QK i `;2iiQ HHT ii2`M  
i? i2 +? i `;2i ? b iQi Hr2B;?i Q7 Ri? i Bi+ M bTHBi mT M/ bb  
T ii2`Mb- /2T2M/BM; QM ?Qr #2M2}+B H Bi}M/b 2 +? QM2X q? i B  
7Q` T `iB+mH `i `;2i 7QHHRb b2i Q7 `mH 2bxjXVA NB Q/B2+mbb2  
iQ bbm`2 i? ii?2 iQi H bmK 7`QK 2 +? T ii2`M Bb R- 2 +? r2B;?i  
;Bp2 Qmi Bb MQ`K HBx2/ rBi? `2bT2+i iQ i?2 bmK Q7 HH r2B;?i  
H;Q`Be`BM i?2 Tb2m/Q@+Q/2X h?2 r2B;?i ;Bp2M Qmi 7`QK 2 +? i  
+ M #2 2Bi?2` TQbBiBp2 Q` M2; iBp2X AM i?2 + b2 i? i Bi Bb M2;  
rBHH +QmMiiQr `/b i?2 iQi Hp Hm2 Bi Bb HHQR2/ iQ ;Bp2 Qmi- K  
rBi?0:5 M0:5 iQ T ii2`M rQmH/ +QmMi 2[m HHv iQr `/b ;BpBM; Qm  
Q7X

"v ;BpBM; 2 +? i `;2i bi iB+ p Hm2 Q7 Ri? i Bi+ M bbB;M BM  
i? i2 +? i `;2i +QMi`B#mi2b 2[m HHv iQ r? i T ii2`M Bb +?Qb2M-

6B;m`2 9Kk2 b+?2K2 Q7 bbB;MBM; r2B;?ib 7`QK 2 +? i`;2i iQ  
iB+2 i? ii?2 bmK Q7 HH r2B;?ib 2`<sup>m</sup> jw(t;2i pBjp2b Qmi-  
Bb 2[m HiQ RX 1 +? T ii2`M`2+2Bp2b T`i Q7 i?Bb iQ  
i`;2i- r?B+? 2[m i2b iQ i?2 iQi H r2B;?i bbB;M2/ iQ i?

i`;2iX A7 i?Bb r2`2 MQii?2 + b2- M Qp2`Hv +iBp2 i`;2i KB;?  
Q`HQR r2B;?ib iQ 2 +? T ii2`M-`2bmHiBM; BM ?B;? bmK Q7  
;Bp2M QmiX J2 Mr?BH2- MQi?2`i`;2i KB;?i bbB;M r2B;?  
;BpBM;Bi HQR iQi H r2B;?i+QMi`B#miBQM X q?2M+QKT`2/ iQ  
Bib +QMi`B#miBQM rQmH/ 2 bBHv/`QrM KQM; HH i?2 Qi?2` +  
+iBp2 i`;2i rQmH/ /B+i i2 r? i T ii2`Mb `2;2M2` i2/X

:YkYS BNj3a03U3N03N,3 R8 i a<3jc

q?2M +QMbB/2`BM; K2i`B+b@# b2/ ;2M2` iBQM H;Q`Bi?K-i?  
Q7 i?2 i`;2ib M/ i?2B` K2i`B+b `2 BKTQ`i MiX q?2M irQ Q`  
;2M2` iBQM H;Q`Bi?K bQK2?Qr ? p2 M 2z2+i QM 2 +? Qi?2`  
H;Q`Bi?K KB;?i MQi T`Q/m+2 QTiBK H`2bmHib- bi?2/2bB`2/  
+QM~B+i rBi? MQi?2`X AM Q`/2` iQ /Bb+mbb i?Bb +QM+2Ti- i  
QB Mi2`/2T2M/2M+~~X~~ QMi;2M2b H- B7 irQ i`;2ib `2 B Mi2`/2T2M  
i? ii?2v KB;?i bQK2?Qr z2+i QM2 MQi?2`/m`BM; i?2;2M2` i  
B Mi2`/2T2M/2M+2 Bb #Qi?`2HB MiQM i?2 K2i`B+ Q7 i?2 i`;2i-  
Q7 i?2;2M2` iBQM 7` K2rQ`F mb2/X \*QMp2`b2Hv- B7 irQ i`;2i  
KQ/2H +QmH/ Hr vb #2;2M2` i2/ rBi? Mv +QK#BM iBQM Q7  
bBM+2 i?2v rQmH/ M2p2` +QM~B+iX

H;Q`Bi?K PJSIh1 @q1A:>ha

BMTmib, . :HQ# H p `B #H2b /2}M2RB HbQ`Bi?KbbB#H2 ?2`  
R,T . h?2 b2i Q7 K2i`B+b M/i`;2i p Hm2pQ7b H2;QMB/iBM HBM2  
k,g . h?2 +m`2MiHv ;2M2` i2/ T`Q+2bb K  
j, Plocation 2 g . h?2 T ii2`MrBM p rQmH/ #2 BMb2`i2/

9, 7mM+iBQMSIh1 @q1A:>hU-g-plocation V . \* H+mH i2b i?2 iQi H  
r2B;?ib bbB;M2/iQ 2 +? T Ti2MM i# 2 2/ QMQ7

8, W:P! R. i?2 b2i Q7 r2B;?ib 7Q` HH TW(p) Bb i 72mr2B;?ii  
Q7 T ii2`M

e, 7Q` p2HP/Q

d, W(p) m2M \*PJSIh1 @q1A:>(f;m;p;g;Plocation )

3, 2M/7Q`

N, `2im`M

Ry,2M/ 7mM+iBQM

H;Q`Bi?K PJSIh1 @q1A:>h

BMTmib, . :HQ# H p `B #H2b /2}M2RB HbQ`Bi?KbbB#H2 ?2`  
R,T . h?2 b2i Q7 K2i`B+b M/i`;2i p Hm2pQ7b H2;QMB/iBM HBM2  
k,m . h?2 K2i`B+ Q7 i?2 i`;2i p Hm2 i? i Bb ;BpBM; Qm  
j,p . h?2 T ii2`Mi? ii?2 r2B;?i Bb ;QBM; iQ #2 bb  
9,g . h?2 +m`2MiHv ;2M2` i2/ T`Q+2bb K  
8,Plocation 2 g . h?2 T ii2`MrBM p rQmH/ #2 BMb2`i2/

e, 7mM+iBQMSIh1 @q1A:>U-m-p-g-plocation V. + H+mH i2b i?2 r2B;?i  
;Bp2M #Qb2/ QM(m)-m(g)- B7Bb BMb2gi2p, BM

d, b\_m P \*G\*IG h1 @ "1L16 (f;m;p;g;Plocation )

3, b\_M p2P \*G\*IG h1 @ "1L16 (f;m;p;g;Plocation )

N, w\_m b\_m=b\_M . i?2 MQ`K HBx\_m iBQM Q7

Ry, `2im`M

RR2M/ 7mM+iBQM

AM i?Bb rQ`F- irQ FBM/b Q7 BMi2`/2T2M/2M+2 rBHH #2 /2}M2/  
rBHH #2 BMH22/2Mi BMi2`/2T2M/2M+2 b i? ii?2 /2}MBiBQM Bib2H  
K2i`B+ Q7 irQ i`;2ib K F2b i?2K /2T2M/2Mi- #2+ mb2 i?2v T `iHv  
K2 bm`2bX bBKTH2 2t KTH2 Bb i?2 MqAN#2` M/7i?2. QiTHBib-  
MmK#2` Q7 ; i2r G b THBM- KQ/2HX A7 KQ/2H + M +QMi BM #C  
M/ P\_@; i2b- i?Bb K2 G M b G?L.i+G\_P\_X h?mb- M BMG\_L2 b2 BM  
rBHH HbQ H2 / iQ M b M+r2B b2 Q7 mH/ K F2 i?2B` i`;2ib BM?2`  
BMi2`/2T2M/2MiX

MQi?2` + b2 Bb r? irBHH #2 /2}M2QBM@Bb2`Q`Mfi BMi2`/2T2M/

r?B+?- b i?2 M K2 bm;;2bib- Bb MQi BM?2`2Mi iQ i?2 K2 bm`2  
i?2Kb2Hp2b- #mi Bb` i?2` /m2 iQ i?2 # bB+ T ii2`Mb mb2/ #v i?  
BM i?Bb + b2 SG:X AK ;BM2 B7 ;2M2` iBQM H;Q`Bi?K + M +?  
T ii2`Mb @ +`2 iBM; M +iBpBiv- Q`M /2Mi BM@ bTHBiXp BQr H2i  
mb b v i? ii?2 ;2M2` iBQM H;Q`Bi?K ? b #22M b2i iQ ;2M2` i2  
bTHBib- #mi QMHv 8 +iBpBiB2bX h?2 MmK#2` Q7 L.@bTHBib  
MQi BM?2`2MiHv /2T2M/2Mi QM 2 +? Qi?2`- bBM+2 //BM; M  
MQi M2+2bb `BHv // MQi?2` L.@bTHBi- M/ pB+2 p2`b X >Q  
7Q`2K2MiBQM2/ ;2M2` iBQM T ii2`Mb p BH #H2- ;2M2` iBM;  
TQbbB#H2- bBM+2 i?2 H;Q`Bi?K rQmH/ Hr vb ;2M2` i2 QM2 +  
M L.@bTHBiX AM Qi?2` rQ`/b- 2p2M i?Qm;? i?2 K2i`B+b `2 M  
QM 2 +? Qi?2`- i?2v `2 /2T2M/2Mi QM 2 +? Qi?2` rBi? `2bT2+  
i2`M- Q` MQM@BM?2`2MiHv BMi2`/2T2M/2MiX h?Bb Bb +im H  
7` K2rQ`F Q7 SG:- r?2`2 ;2M2` iBM; T `HH2H 2t2+miBQM T i  
+iBpBiB2bX \*QMp2`b2Hv- B7 i?2 T ii2`M ;2M2` iBM; M L.@b  
M +iBpBiv- Bi rQmH/ BM/22/ #2 TQbbB#H2 iQ +`2 i2 bm+? K  
; i2r vb b +iBpBiB2bX h?2 ;2M2` iBQM Q7 T ii2`M z2+iBM  
z2+i i?2 Qi?2`- M/ i?mb i?2 K2i`B+b rQmH/ MQi #2 BMi2`/2T2  
q?BH2 i?2 #Qp2 Bb `iBpB H 2t KTH2- i?2 b K2 bBim iBQM  
2 +? iBK2 i?2 ;2M2` iBQM Q7 +2`i BM T ii2`M z2+ib KQ`2 i  
iBK2X 6Q` 2t KTH2- i?2 +`2 iBQM Q7 HQQT rQmH/ z2+i i?2  
#mi Bi rQmH/ HbQ z2+i Bib +QMi`QH ~Qr +QKTH2tBiv- b Bi  
; i2r vb- i?mb BMi`Q/m+BM; KQ`2 TQbbB#H2 bi i2b iQ i?2 KQ  
i?2 BM/2T2M/2M+2 Q7 K2i`B+b Bb Hqr2bi r?2M i?2 K2i`B+b `2  
Q` BMpQH2b i?2 b K2 K2 bm`2b- BM r?B+? + b2 r2 KB;? i? p2  
BM?2`2Mi BMi2`/2T2M/2M+2X LQi2 i? i irQ K2i`B+b + M +Q`2H  
p Hm2b 7Q` +QHH2+iBQM Q7 KQ/2Hb- r?BH2 biBHH ? pBM; M  
BMi2`/2T2M/2M+2X

:YkYI KRNRjRNC,Cjw R8 K3jaC,c

h?Bb i?2bBb rBHH K F2 /BbiBM+iBQM #2ir22M KQMqiQMB+  
rBi?`2; `/b iQ i?2 T ii2`Mb mb2/ #v i?2 7` K2rQ`FX h?Bb Bb i  
rQ`F- M//` rb BMbTB` iBQM 7`QK i?2 MQiBQM BM K i?2K iB+k  
A7 K2i`B+ Bb KQMqiQMB+- Bi Bb 2Bi?2` MQM@BM+`2 bBM;  
;2M2` iBQM Q7 i?2 KQ/2H- r?2M mbBM; +2`i BM b2i Q7 T`Q  
i?2 MmK#2` Q7 +iBpBiB2b b M 2t KTH2- i?Bb rBHH Hr vb #2  
/m`BM; ;2M2` iBQM- b MQ T ii2`Mb BM i?2 7` K2rQ`F rBHH 2p  
q?2M K2i`B+ Bb MQM@/2+`2 bBM; rBi?`2bT2+i iQ b2i Q7  
`272`2/ iQ QMqiQMB+ HHv BMX` Q bBM B K2i`BQ MQiQMB+ K2i  
HbQ #2 KQMqiQMB+ HHv /2+`2 bBM;- r?B+? K2 Mb i? i Bi + M  
iQ i?2 b2i Q7 T`Q/m+iBQM T ii2`MbX PM i?2 Qi?2` ? M/- MQM@  
#Qi? BM+`2 b2 Q`/2+`2 b2 /m`BM; ;2M2` iBQM- b i?2 //BiBQM

BM+`2 b2 Q` /2+`2 b2 i?2KX LQM@KQM QiQMB+ K2iHb+H p2 i?2  
 K tBKX h?Bb + M 7Q` 2t KTH2 ? TT2M B7` K2i`B+ Bb #2BM; ;2M2`  
 p Hm2- #mi BM Q`/2` iQ BM+`2 b2 7`QK Bib +m``2Mip Hm2 iQ i?2  
 iQ /2+`2 b2X b /Bb+mb ~~2RBB~~bb2 +MBiQ Qp2 +? HH2M;2 iQ i?2 H;  
 M/ Bb i?2`27Q`2 BKTQ`i Mi iQ MQi2 ?2`2X

:YkYk #3N3~j R8 T jj3aNc

h?2 BMTmi iQ i?2 #2M2}i + H+mH ~~BBQM~~ QM QH/ Q` BB? Ki Q7 HH- B  
 iQ FMQR r?B+? +QK#BM iBQM Q7 K2i`B+ M/ T ii2`M i?2 #2M2}i B  
 BM i?2 7Qm KM Q7X Ai HbQ M22/b iQ FMQR i?2 bi i2 Q7 i?2 +m``2M  
 KQ/2Hg BQ T bb2/- b r2HH b r?B+? T ii2`M i?2 ;2M2` i2/ T ii2`M  
 bg M /location X HQM; rBi? i?2 i `;2i p Hm2- Q7i i? 2Mk2i2B+? Bb iQ  
 + H+mH i2 ?Qr Km+? +HQb2` iQ i?2 i `;2i p Hm2 ;2M2` iBM; i?2 T  
 i?2 KQ/2Hd BbM HBYM Z H; Q` dKi?K

h?2 ;Q H 7Q` i?2 `mH2b i? i ;Qp2`M i?2 #2M2}i Q7` T ii2`M Bb  
 b?QmH/ K F2 bm`2 i? i i?2 i `;2i p Hm2 Bb`2 +?2/X a2+QM/- Bi  
 i? i i?2 ;2M2` iBQM Q7 i?2 KQ/2H i2`KBM i2b i i?2 `B;?i iBK2- K2  
 i `;2i p Hm2 Bb`2 +?2/- Q` #2ii2` bQHmiBQM + M MQi #2`2 +?2  
 biQTX A7 MQi- Bi b?QmH/ +QM iBMM2X hQ 7 +BHBi i2i?Bb- i?2`r  
 #22M bTHBi BM irQ- r?2`2 QM2 T `i bi i2b i?2 #2M2}i Q7 +?QQbB  
 Q7 /Bbi M+2 7`QK i?2 +m``2Mip Hm2 iQ i?2 i `;2i p Hm2- M/ MQ  
 +?QQbBM; i?2 T ii2`Mb BM i2`Kb Q7 i2`KBM iBQM Q7 i?2 ;2M2` i  
 + HH2/K2i2B+ #2 M2i2`KBM iBQM #22M2}i iBp2HvX

h?2 B/2 Bb i? i MQ`K HHv- i?2 K2i`B+ #2M2}i Q7 i?2 T ii2`M b  
 T ii2`M Bb +?Qb2MX h?2 K2i`B+ #2M2}i Bb + H+mH i2/ bBKTHv b  
 iQ i?2 i `;2i p Hm2 7`QK ;2M2` iBM; T ii2`MX AM Qi?2` rQ`/b- i  
 ;Bp2M b K2i`B+ #2M2}i =  $\frac{j_{d\text{after}} j_{j\text{before}} j}{i ;2i p Hm2}$  r?2 d2Bb i?2 /Bbi M+2  
 7`QK i?2 +m``2Mip Hm2 iQ i?2  $\frac{j_{d\text{after}} j_{j\text{before}} j}{i ;2i p Hm2}$  M d<sub>before</sub> =

jt m<sub>before</sub>j `2 i?2 #bQHmi2 /Bbi M+2b 7i2` M/ #27Q`2 i?2 T ii2`M rC  
 BM i?2 +m``2Mi KQ/2H- `2 b B2i?2Epi2H2-i p? 2i r2 2i Q7hK Bib B2 Mb  
 i? i i?2 +HQb2` T ii2`M rBHH #`BM; K2i`B+ iQ Bib i `;2i p Hm2-  
 Bb- b i?2 K2i`B+ #2M2}i rBHH #2 QBB2BpX ABX2X i?2 /Bbi M+2 Bb  
 i?2 #2M2}i rBHH #2 M2; iBp2- BX2X Bi Bb MQi/2bB` #H2X h?2 /2}  
 Bb + H+mH i2/ B MX H; Q` Bi?K

>Qr2p2`- i?2`2 `2 +2`i BM + b2b r?2`2 r2 HbQ ? p2 rBb?2b 7Q`  
 TQi2MiB H Q7 i?2 H; Q`Bi?K- r?B+? Bb ;Qp2`M2/ #Empty i?2 MmK #2`  
 BM i?2 KQ/2HX h?2b2 + b2b + M Q++m` r?2M i?2 bT2+B}+ K2i`B+  
 p Hm2- Q` Bb rBi?BM i?2 i?`2b? Q HWCC7i B2-i/2;2M2/ Hm2- BM r?B+  
 + b2 Bi Bb #2M2}+B H 7Q` i?2 K2i`B+ iQ i2`KBM i2 ;2M2` iBQM Q7  
 TQi2MiB HHv #`BM; i?2 KQ/2H 7m`i?2` r v 7`QK i?2 i `;2i p Hm2  
 i2`KBM iBQM #2M2}i rBHH`2im`M ?B;? #2M2}i 7Q` T ii2`M bi? i  
 TH +2?QH/2`b BM i?2 KQ22 QX +QK Q7 #2 M /2}M2/ 7Q` i?2 MmK #2



Q7 TH +2?QH/2`b BM KQ/2H-r?B+? Bb ` M;2 7Q` i?Bb MmK#2  
 #2 rBi?BM /m`BM; i?2 ;2M2` iBQM H;Q`Bi?KX h?Bb` M;2 Bb /  
 8 TH +2?QH/2`b- M/ 2Mbm`2b i? i i?2 H;Q`Bi?K /Q2b MQi ;2i  
 bm+? i? i Bi #2+QK2b ? `/2` iQ biQT r?2M i `;2i p Hm2b `2`2  
 rBHH MQi BM /p2`i2MiHv i2`KBM i2 r?BH2 i?2 i `;2i p Hm2b ?  
 h?Bb Bb` HbQ /2b+`B# 2/QB7M? 2;Tb`Bm? @ +Q/2X  
 h?2 i2`KBM iBQM M/ K2i`B+ #2M2}ib `2 +QK#BM2/ BMiQ i?  
 i?2v ? p2 i?2 b K2 2z2+i QM i?2 iQi H #2M2}iX h?Bb K2 Mb i?  
 bm`2b jK2i`B+ #2M2}i2`KBM iBQM i#2M2Mi iBQM #2M2}i Bb  
 K2 Mb i? i #2M2}i2`B+ #2M2}iKBM iBQM i#2M2Mi iBQM #2M2}i  
 M/ #2M2}i2i`B+ #2M2}iKBM iBQM #2M2}i2i? i i?Bb #2M2}i Bb +  
 H i2/ 7Q` 2 +? +QK#BM iBQM Q7 K2i`B+ M/ T ii2`M- M/ Bb i?2  
 #v H;Q` Bx?K

---

H;Q`Bi?K G\*IG h1@"1L16Ah

---

BMTmib, . :HQ# H p `B #H2b /2}M2RB HbQ`Bi?KbbB#H2 ?  
 R,T . h?2 b2i Q7 K2i`B+b M/ i `;2i p Hm2pQ7b /2;}M2B/i BM HB  
 k,m . h?2 K2i`B+ Q7 i?2 iT(m)i ip Hm?2 #2M2}i Bb + H+mH i2  
 j,p . h?2 T ii2`M i? i i?2 #2M2}i Bb + H+mH  
 9,g . h?2 +m`2MiHv ;2M2` i2/ T`Q+2b  
 8,Pllocation 2 g . h?2 T ii2`MrB M p rQmH/ #2 BMb2`i2/  
 e, 7mM+iB G\*IG h1@"1L16Ah-m-p-g-Pllocation V . + H+mH i2b i?2  
 #2M2}iT(Q)`Q7 ;2M2`p iBMB M i?2 T H Pllocation Q7  
 d, b\_m \* G\*IG h1@J1h\_A\*@"1L16Ah(m);p;g;Pllocation ) . h?2  
 K2i`B+ #2M2}i  
 3, b\_t \* G\*IG h1@h1\_JAL hAPL@"1L16Ah(m);p;g) . h?2  
 i2`KBM iBQM #2M2}i  
 N, B\_j > 0 i?2M A7 i?2 i2`KBM iBQM #2M2}i Bb MQi x2`Q- #Qi  
 i2`KBM iBQM #2M2}i K ii2` 2[m HHv  
 Ry, b\_b  $\frac{ib_m j}{ib_j}$  . 1Mbm`2b??ib i?2 b K2 K ;M B\_m/2 b  
 RR, `2im b\_m + b  
 Rk, 2Hb2  
 Rj, `2im b\_m  
 R9, 2M/ B7  
 R8,2M/ 7mM+iBQM

---

:YkY: QUjCLCyCN<j@3 KR03I bj j3

h?2 B/2 Q7 + H+mH iBM; i?2 #2M2}i Q7 T ii2`M # b2/ QM ?Qr  
 K2i`B+ iQ i `;2i p Hm2 K2 Mb i? i i?2 H;Q`Bi?K + M #2 b22M

---

H;Q`Bi?K\*G\*IG h1@J1h\_A\*@"1L16AhX ~~222RQ2+i/BQM~~ BTiBQM  
 Q72KQp2SH +2?QH/2`bUV

---

BMTmib,  
 R,m . h?2 K2i`B+ i? ii?2 #2M2}i Bb + H+mH i  
 k,t . h?2 i `;2i p Hm2 7Q`  
 j,p . h?2 T ii2`M i? ii?2 #2M2}i Bb + H+mH i  
 9,g . h?2 +m``2MiHv ;2M2` i2/ T`Q+2bb K  
 8,Plocation 2 g . h?2 T ii2`MrB M p rQmH/ #2 BMb2`i2/

e, 7mM+iBQMIG h1@J1h\_A\*@"1L16Ahp-g-plocation V .  
 \* H+mH i2b i?2 K2i`Bm @2M2M27QBM;  
 d, d<sub>before</sub> j t m(`2KQp2SH +2? Qd)/2`b . .Bbi M+2 UmmK2`B+ H  
 /Bz2`2M+2V iQ i `;2i p Hm2M#27Q22BM  
 3, g . g rBi p BMb2`i2/ BMPlocation+2 Q7  
 N, d<sub>after</sub> j t m(`2KQp2SH +2? Qd)/2`b . .Bbi M+2 UmmK2`B+ H  
 /Bz2`2M+2V iQ i `;2i p B b m b i g 2/ BM  
 Ry, d<sub>after</sub> d<sub>before</sub>  
 RR, `2im`M<sub>t</sub><sup>d</sup>  
 Rk,2M/ 7mM+iBQM

---

T`Q#H2K- r?B+? Bb #Qmi`2/m+BM; i?2`2H iBp2/Bbi M+2 #2ir2  
 i?2 K2i`B+b M/i?2B`i `;2i<sup>d</sup>p- H@22-B?X22i`B+X h?2 H;Q`Bi?K +  
 b22M b M TT`QtBK iBQM Q7 i?2 QT i B~~K BM iHBM2~~ THQ@H2iK`KQ`  
 d-BM r?B+? i?2 H;Q`Bi?K b?QmH/ KBMBKBx2 i?2 #bQHmi2 p2`  
 7Q<sub>t</sub><sup>d</sup>- Q` KBMBKBx2 i?2 2m+HB/2 M H2M; i? Q7 i?2 p2<sup>d</sup>iQ` Q#i BM  
 7Q` HH K2i`B+bX q?BH2 Dmbi M TT`QtBK iBQM- bBM+2 i?Bb  
 M/i?2 i2`KBM iBQM #2M2}i + M HbQ TH v `QH2- Bi BHHmbi`  
 H;Q`Bi?K r2HHX Ai HbQ HHQrb mb iQ i HF Q7 KQ/2H bi i2- i?  
 ? TT2Mp<sub>t</sub><sup>d</sup> 7Q` HH K2i`B+b /2+`2 b2bX q?2M i?2 KQ/2H bi i2  
 BKT`Qp2/ Mv HQM;2`- i?2 KQ/2H bi i2 Bb QT i BKBx2/X

AM T`BM+BTH2- i?2`2`2 KmHiBTH2 r vb Q7 + H+mH iBM; i?Bb  
 bi i2- #v +?QQbBM; 2 +? T ii2`MX 6Q` +2`i BM +QK#BM iBQMb C  
 i?2 /Bz2`2M+2 BM /Bbi M+2 Bb Hr vb i?2 b K2- `2; `/H2bb Q7 i?  
 KQ/2HX 6Q` 2t KTH2- T`Q/m+BM; Kmim H 2t+HmbBQM T ii2`M r  
 iQ i?2 MmK#2` Q7 L.@; i2r vb- MQ K ii2` ?Qr K Mv Qi?2` L.@; i2  
 KQ/2HX AM bm+? + b2b- Bi rQmH/ #2 T Q-bb B#H2?Q Bi2@rHQ;` K  
 QMHv ? p2 iQ #2 HQQF2/ mT i`mM@iBK2X h?Bb Bb ?Qr2p2` MQi  
 K2i`B+@T ii2`M +QK#BM iBQMX PM2 2t KTH2 Bbi?2/B K2i2`- r?  
 +?Qb2M T ii2`M r b HQ+ i2/ QM i?2 HQM;2bi T i? - ;Bp2M i? ii?2  
 I > 0X >Qr2p2`- B7 i?2 b K2 T ii2`M r b ;2M2` i2/ QM b?Q`i2` T  
 MQi M2+2bb `BHv #2 i?2 + b2X AM Qi?2` rQ`/b- i?2 +? M;2 BM /B  
 +m``2Mibi i2 Q7 i?2 KQ/2HX MQi?2` +QKKQM + b2 r?2`2 i?2 /Bz2`

H;Q`Bi?K\* 3G\*IG h1@h1\_JAL hAPL@"1L16AhX9aX2RQb2+iBQM  
b+`BTiBQM Q7 iBb 62i;2Q hb? M`2 P7\*QNK/7Q`iU2/h` ;2iUV

BMTmib,  
R,m . h?2 K2i`B+ i? ii?2 #2M2}i Bb + H+m  
k,t . h?2 i ` ;2i p Hm2 7Q`  
j,p . h?2 T ii2`M i? ii?2 #2M2}i Bb + H+m  
9,g . h?2 +m``2MiHv ;2M2` i2/ T`Q+2bb

8,7mM+iBQMIG h1@h1\_JAL hAPL@"1L16A-p-gV + H+mH i2b  
i?2 i2`KBM iBQM #2M7;2 M Q`p iBQM;

e, n\_p . LmK#2` Q7 TH +2?QBQ`b  
d, n . /Bz2`2M+2 BM TH +2?QH/2`bBQ`i2` BMi`  
3, b?QmH/.2+`2 b2SH +2?QH/2`b? M`2 P7\*Q(K7)QPI`  
`2 +?2/h` ;2i;t) . q?2i?2` i?2 MmK#2` BQ`b?QmH/ /2+`2 b2  
N, b?QmH/AM+`2 b2SHb+2?QH/2`b? M`2 P7\*(Qp)7Q`i  
!`2 +?2/h` ;2i;t) . q?2i?2` i?2 MmK#2` BQ`b?QmH/ BM+`2 b2

Ry, Bb?QmH/.2+`2 b2SH+2?QH/2`b  
RR, B7n< 0 i?2M  
Rk, `2im`M  
Rj, 2Hb2  
R9, `2im`QR  
R8, 2M/ B7  
Re, 2Hb2bB?QmH/AM+`2 b2SH+2?QH/2`b  
Rd, B7n> 0 i?2M  
R3, `2im`M  
RN, 2Hb2  
ky, `2im`QR  
kR, 2M/ B7  
kk, 2Hb2  
kj, `2im`M  
k9, 2M/ B7  
k8,2M/ 7mM+iBQM

MQi #2 T`2/2i2`KBM2/ Bb rBi? +2`i BM K2i`B+b- r?B+? `2 /2i2`  
i?2 + b2 i? ii?2 K ;MBim/2 Q7 i?2 /Bz2`2M+2- M/ r?2i?2` Bi Bb  
x2`Q- Bb /2T2M/2Mi QM i?2 p Hm2b Q7 i?2 MmK2` iQ` M/ /2MQK  
Bb //2/X M 2t KTH2 Q7 bm+? K2i`B+ Bb +QMM2+i2/M2bb- r  
+QMi`B#mi2b KQ`2 r?2M i?2`2 `2 72r2` 2/;2b- i? M r?2M i?2`  
2t KTH2 Bb i?2 +Q2{+B2Mi Q7 +QMM2+iBpBiv- ;Bp2M b i?2` i  
r?B+? rBHH Hr vb ;Q iQr `/b i?2 p Hm2 R b bm#b2[m2Mi b2[m  
+iBpBiv `2 //2/iQ i?2 KQ/2HX A7 i?Bb ? TT2Mb b i?2 }`b i?2  
2M/ MQ/2b- i?2 p Hm2 rBHH BM+`2 b2 iQr `/b R 7`QK yX8- M/ B

H `;2 MmK#2` Q7 ; i2r v T ii2`Mb- bm+? i? i i?2 K2i`B+ Bb ?B;?2`  
 b2[m2M+2 T ii2`M rBi? M +iBpBiv rQmH/ /2+`2 b2 i?2 p Hm2 Q  
 6Q` i?2 #Qp2 + b2b- MQi?2` r v Q7 /2i2`KBMBM; i?2 /Bz2`2M+  
 i `;2i p Hm2 Bb M22/2/X AM i?Bb rQ`F- i?2 /Bz2`2M+2dBm /Bbi M+  
 Bb + H+mH i2/ #v bBKmH iBM; i?2 ;2M2` iBQM Q7 i?2 T ii2`M QM  
 + H+mH iBM; i?2 M2r p Hm2 Q7 i?2 K2i`B+- iQ +QKT `2 Bi iQ i?2 B  
 T`Q+2bb + M #2 b22MdBM? BbQK2Bii?Q/ r b +?Qb2M #2+ mb2 Q7 Bib  
 M/ bBKTHB+Biv- bm+? i? i HH T ii2`M@K2i`B+ +QK#BM iBQM b  
 i? i i?2 bBKmH iBQM Bb `2HB Mi QM FMQRBM; i?2 +m`2Mi bi i2 Q  
 r?B+? Bb 2tTH BM2/ BM 7m`i?2XjX28 BH BM b2+iBQM

M Hi2`M iBp2 iQ /2i2`K B B i B i M H i B Q M i? i r b +Q M b B /2`2/ r b i C  
 bT2+B}+ T`2/2i2`KBM2/`mH2b 7Q` /2i2`KBMBM; i?2 /Bz2`2M+2 B  
 # b2/ QM b2i Q7 `mH2b QM i?2 +m`2Mi bi i2 Q7 i?2 KQ/2HX q  
 KB;?i +?B2p2 #2ii2`mMMBM; iBK2 7Q` +QKTH2t K2i`B+b- bBM  
 QMHv ? p2 iQ #2 HQQF2/ mT- i?2 /B{+mHiv Q7 BKTH2K2MiBM; b  
 ` iBQ@# b2/ K2i`B+b- r b +Q M b B /2`2/ ?B;? b +QKT `2/ iQ i?2 /  
 i?2 7` K2rQ`F iQ bmTTQ`i i?2`mM@iBK2 2p Hm iBQM Q7 K2i`B+b  
 9XjXeHbQ- `2[mB`BM; i?2 BKTH2K2Mi iBQM Q7 `mH2b bT2+B}+ i  
 rQmH/ HbQ K2 Mi? i M 2ti` Qp2`?2 / BM i?2 BKTH2K2Mi iBQM C  
 #2 B Mi`Q/m+2/- r?B+? Bb mM/2bB` #H2X

:YkY9 2q In jCRN R8 TaR,3cc KR03I K3jaC,c

.m`BM; T`Q+2bb ;2M2` iBQM BMbi M+2- i?2 H;Q`Bi?K +QM iBM  
 T`Q# #BHBiB2b Q7 2 +? T ii2`M- # b2/ QM i?2 +m`2Mi bi i2 Q7 i  
 Bib /2bB`2/ bi i2X aBM+2 KQ/2Höb bi i2 Bb /2}M2/ #v Bib K2i`  
 i?Bb K2 Mb i? i Bi K2 bm`2b i?2 K2i`B+b Q7 i?2 +m`2Mi KQ/2H-  
 i?2 /2bB`2/ p Hm2 7Q` i?2 K2i`B+b- BM Q`/2` iQ /2+B/2 r? i T ii2  
 h?Bb K2 Mb i? i i?2 ;2M2` iQ` M22/b r v Q7 miQK iB+ HHv + H+  
 Q7 T`Q+2bb KQ/2Hb i`mM@iBK2X h?Bb Bb /QM2 b T`i Q7 i?2 -  
 Q7 ;2M2` iBM; T ii2dM/BQ7HBMQ2bX

aBM+2 i?2 ;2M2` iQ` Bb ?2 pBHv /2T2M/2Mi QM K2i`B+b + H+  
 K2 bm`2 HH K2i`B+b i2p2`v`2+m`bBp2 Bi2` iBQM- Bi Bb p2`v /2T  
 [m HBiB2b- bT2+B}+ HHv Bib iBK2 +QKTH2tBiv M/ bmtTTQ`i2/ K2  
 i 2p2`v Bi2` iBQM- Bib /B`2+i BKT +i QM i?2 iBK2 +QKTH2tBiv B  
 /Bb+mbb2/ 7m`i?2 9BM p22+MBB iM+QK2b iQ i?2 bmtTTQ`i2/ K2i`B+  
 + H+mH iQ`- bBM+2 i?Qb2 bmtTTQ`i2/ #v i?2 H;Q`Bi?K M22/ iQ  
 Bi2` iBQM- i?2 H;Q`Bi?K + M QMHv bmtTTQ`i i?Qb2 K2i`B+b i? i  
 i?2 + H+mH iQ`X h?2 bmtTTQ`i2/ K2i`B+b Q7 i?2 B X Q M Bi?K + M #  
 8Xk

:YkYf bnUURajCN< `nNAjCL3 2q In jCRN

q?2M K2i`B+b `2 2p Hm i2/ i`mM@iBK2- i?Bb Bb /QM2 QM i  
;2M2` i2/ T`Q+2bb KQ/2HbX >Qr2p2`- BM Q`/2` iQ /Q i?Bb QM  
KQ/2H i 2 +? Bi2` iBQM- +2`i BM KQ/B}+ iBQMb iQ i?2 SG: ;2  
M22/2/X

q?2M i?2 SG: 7` K2rQ`F `2+m`bBp2\_Hv1@S@B1hBp H2Mi- Bi  
r Bib mMiBH i?2 `2+m`bBp2 + HH `2im`Mb iQ BMb2`i i?2 ;2M2`  
T ii2`Mosen - M/+QMM2+i Bi iQ i?2 `2bi Q7 i?2 T ii2`MX >Qr2p2`-  
2 +? + HHLQZ h1@S-hr?2;2M2` i2/ T ii2`M Bb MQi +QMM2+i2/ i  
T `ib Q7 i?2 KQ/2H- mMiBH +QMi`QH `2im`Mb iQ Bib + HH2`X A  
;2M2` i2b KQ/2H +QKTQM2Mib BM iQT@/QrM 7 b?BQM- M/ +  
mT 7 b?BQMX A7 K2i`B+ Bb + H+mH i2/ 7Q` i?2 T`Q+2bb KQ  
MQi #2 +QMM2+i2/- bm+? i? i i?2`2 Bb MQ BM7Q`K iBQM #Q  
KQ/2H- r?B+? Bb M2+2bb `v 7Q` K2i`B+b bm+? b i?2 /B K2i2`  
9XjBM r?B+? i?2 +QKTQM2Mib Q7 2 +? T ii2`M `2;2M2` i2/ QM  
`2+m`bBQM- r?BH2 i?2 b K2 +QKTQM2Mib `2 MQi +QMM2+i2/  
# +F ômTô i?2 `2+m`bBQMX

AM Q`/2` iQ bQHp2 i?Bb T`Q#H2K- 7` K2rQ`F QMM#Qib ;2M  
KQ/2Hb BM iQT@/QrM 7 b?BQM Bb M22/2/X hQ +?B2p2 i?Bb  
TH +2? QH/2`-BM 2: 421\_ h1@S-hr?B+L? Bi BMb2`ib BMiQ i?2 ;2M  
KQ/2H BM TH +2 Q7 i?2 T ii2`Mb i? i `2 iQ #2 ;2M2` i2/ #v b  
:1L1\_ h1@S@h1Hb-NBM?HBmK2 Mb i? i + HHb 7m`i?2` /QrM i?  
rBHH? p2 ++m` i2 BM7Q`K iBQM #Qmi i?2 ~Qr bi i2 Q7 i?2 K  
2p Hm i2 K2i`B+b 7`QK i?Bb bi i2X h?Bb M2r 9X9B2K 2?Bb+0?Qr  
#Qi? i?2 ;2M2` iBQM M/ +QMM2+iBQM Q7 +QKTQM2Mib ? TT  
`2+m`bBQM- BX2X #27Q`2 +QMb2+miBp2 `2+m`bBp2 + HHb `2

6B;m`2 9Xj?2K2 7Q` ;2M2` iBM; T ii2`Mb BM i?2 SG: 7` K

6B;m`2 9X92 M2r b+?2K2 7Q` ;2M2` iBM; T ii2` Mb- r?B+? HHQrb`  
m iBQM Q7 K2i` B+b QM mM}MBb?2/ KQ/2HbX

:2M2` iBM; TH +2?QH/2` iQ +?B2p2 iQT@/QrM +QMM2+iBQM  
TQM2Mib BMi`Q/m+2b MQi?2` T`Q#H2K- r?B+? Bb ?Qr iQ ? M/H  
r?2M 2p Hm iBM; K2i`B+X aBM+2 i?2 TH +2?QH/2` iQ#22b2Mib  
;2M2` i2/- #mi? b MQi #22M bQ v2i- Bi Bb BM 7 +i M 2KTiv T ii2`  
iQ bFBTT ii2`MX h?Bb Bb HbQ `2~2+i2/ #v i?2 bi`BM; `2T`2b2M  
b<sub>empty</sub> = - r?B+? Bb i?2 b K2 b bFBTT ii2`MX h?Bb K2 Mb i? i B  
TQ`i i?2 `mM@iBK2 2p Hm iBQM Q7 K2i`B+b- HH TH +2?QH/2` b  
KQ/2H `2 i`2 i2/ b 2KTiv bi`Bm; b-; b<sub>empty</sub> + i? # "; Pafter "="

"Pbefore ; ; Pafter "=" Pbefore ; Pafter " X  
h?2 iBK2 +QKTH2tBiv Q7 2p Hm iBM; 2 +? K2i`B+ /2T2M/b QM  
i BM K2i`B+b `2 7 B`Hv bBKTH2- M/ + M #2 +QKTmi2/ BM +QMb  
bm+? Bb i?2 MmK#2` Q7 ; i2r vb- r?B+? BmpQH p2b +QmMiBM; i?2  
i?2 T`Q+2bb KQ/2H- r?B+? + M #2 /QM2 BM HBM2 `Q` +Qmbi Mi  
/ i bi`m+im`2 i? i`2T`2b2Mib i?2 T`Q+2bb KQ/2HX Pi?2` K2i`B+  
H i2- bm+? b +v+HB+Biv- r?B+? BmpQH p2b bQH pBM; i?2 T`Q#H  
/B`2+i2/ ;` T?- r?B+?? b b2p2` H`2b2 `+? T T2`b /Bb+mbbBM; T  
b (8jd)- r?B+? HH i F2 bB;MB}+ Mi iBK2 iQ +QKTmi2- BX2X KQ`  
iQ i?2 bBx2 Q7 i?2 ;` T`Q+2bb KQ/2H- r?B+? + M #2 /QM2 BM HBM2 `Q` +Qmbi Mi  
i F2b + M ? p2 #B; BKT +i QM i?2 iQi H `mMMBM; iBK2 Q7 i?2  
r?2M Bi Bb +QKTH2tX } ;m`2 Q7 i?2 BKTH2K2Mi2/ K2i`B+ + H+mH  
iBK2b + M #2 b22 8XBM/8 XkH2

:Y: `nNNCN< jCL3

q?BH2 i?2 `mMMBM; iBK2 Q7 i?2 H;Q`Bi?K Bb MQi K DQ` `2 Q7  
2ti2MbBQM Q7 i?2 SG: ;2M2` iBQM 7` K2rQ`F T`QTQb2/ +QM iBM

Q7 +QKTmi iBQMX h?Bb b2+iBQM rBHH T`2b2Mi #`B27 M Hv  
7` K2rQ`F- M/ B/2MiB7v r? i Bb HBF2Hv iQ #2 i?2 KQbi iBK2 +C  
`mMMBM; iBK2 Q7 i?2 H;Q`Bi?K Bb iQ #2 BKT`Qp2/- i?2 B/2M  
+ M/B/ i2b 7Q` BMbT2+iBQMX

h?2 Q`B;BM H ;2M2` iBQM 7` K2rQ`F Q7 SG: Bb p2`v # bB+-  
Tmi iBQMX bbmKBM; i? ii?2 ;2M2` i2/T`Q+2bb KQ/2Hb `2 ;2  
bB;MB}+ MiHv H `;2` i? M i?2 MmK#2` Q7 T ii2`Mb- i?2 KQbi i  
i?2 H;Q`Bi?K rBHH HBF2Hv #2 i?2 MmK#:2`LQ7 h21+@nS bBp12`LUM  
2[mBp H2MiX q?BH2 i?2`2 `2 MQ ;m ` Mi22b- BiBb`2 bQM #H  
Q7 + HHh iQ h1@S hBb`L`QVTQ`iBQM HQQ i?2 bBM2` i2/ KQ/2H  
BM i?2 2M/X h?Bb K2 Mbi? i i?2 Q`B;BM H 7` K2rQ`F Q7 SG:  
iBK2 Q7 7Q` ;2M2` iBM; bBM;H2 KQ/2H- r?B+? Qn Mb `mMM  
r?2M ;2M2`n iBM/2HbX

AMbi2 / Q7 Dmbi mbBM; T`2/2i2`KBM2/ r2B;?ib 7Q` 2 +? T ii  
rQ`F +QKTmi2b i?2b2 r2B;?ib: 1iL2\_+h1+@SHhBM`HBMPB+? Bb  
[mBi2 +QKTmi iBQM HHv /2K M/BM;X " bB+ HHv- 7Q` 2 +? T  
Tmi2b i?2 bmK- 7Q` HH bT2+B}2/ K2i`B+b- Q7 i?2 MQ`K HBx  
T ii2`M- i?2 H ii2` Q7 r?B+? `2[mB`2b +QKTmiBM; i?2 #2M2}i C  
i? i K2i`B+X aBM+2 i?2 MmK#2` Q7 T ii2`Mb `2 +QMbi Mi- i?E  
iBK2 Q7 j) iBK2 Q7 Lu 6AVX VbbmKBM; i? i +QTvBM; M/ +QMp2`i  
`2MiHv ;2M2` i2/7Q/2BKmH iBQM T2K`Qp2b2H B2P QiHf2 bbUV  
O(s) iBK2- r?2B2 i?2 bBx2 Q7 i?2 ;2M2` i2/\*KQ`2GH h?@2 M L?26 Ah  
7mM+iBQM i F2b #2 i?2 p2` HQM; i?2 +QKTmi iBQM Q27biX2 K2i  
b /Bb+mbb2/ B Mxj-Xie3 B QMK2 Bi i F2b iQ +QKTmi2 i?2 p Hm2 Q  
?B;?Hv /2T2M/2Mi QM i?2 K2i`B+ Bib2H7- M/ +QmH/ p2`v r2HH  
iQ- Q` HQM;2` i? M XBK?22 i?2 7Q`2- bi iBM; `mMMBM; iBK2 7Q` i  
/B{+mHi- #mi K FBM; i?2 bbmK TiBQM i? i + H+mH iBM; i?2 KQ  
HQM;2` i? M + Q M2HBM2P JSIh1 @q17Am Mh+i B QMjMjF2h  
iBK2- r?2`2 Bb i?2 iBK2 Bi i F2b iQ +QKTmi2 i?2 KQbi +QKTH  
H2 /b iQ iQi H`mM Q(B Ms; jilB jk 2i Q7 - 7Q` r?B+?>= O(s)- Q`  
i H2 Q(n s^2 jMj)X

GQQFBM; i i?2 `mMMBM; iBK2 Q7 i?2 H;Q`Bi?K- B7 bbmK  
T ii2`jMjBb bB;MB}+ MiHv bK HH2`i? M i?2 p2` ;2 bBx2 Q7 ;2M  
i?2M i?2 i2`Kb i? i `2 ;QBM; iQ #2 KQbi bB;MB}+ MiMQ i?2 `m  
nX aBM+2 i?2 +QM i`B#miBQM Q7 i?Bb rQ`F QMst+vM/K2 Q M B M2`K  
t<sub>metric</sub> >= O(s)- i?2 iBK2 7Q` +QKTmiBM; K2i`B+b Q7 i?2 KQ/2H ? p  
BKT +i QM i?2 iQi H`mMMBM; iBK2X

h?Bb T ;2 ? b #22M BMi2MiBQM HHv H27i #H MF



+ ? Ti2` 9

b R 8 j s a 3  
B L U I 3 L 3 N j j C  
/ 3 j C l c

h?Bb +? Ti2` /2b+`B#2b i?2 BKTH2K2Mi iBQM Q7 i?29-H;Q`Bi?  
r?B+? Bb mb2/ iQ Q#i BM i?2 `x b m 2 i / 2 Q b 7 r ? Q Ti2`MQi BMi2`2bi  
i?2 /2i BHb Q7 i?2 BKTH2K2Mi iBQM Q7 i?2 H;Q`Bi?K b?QmH/  
rBi?Qmi HQbBM; Qmi QM BM7Q`K iBQM bB;MB}+ Mi iQ i?2 +Q  
i?2 2t+2TiBQM Q7 i?2 HBbi Q7 BKTH2K2Mi28 XRMi/8BXK+ H+mH iC  
h?2 H;Q`Bi?K ? b #22M BKTH2K2Mi2/ b M 2ti2MbBQM iQ i?2  
i?2 bQm`+2 +Q/2 Bb Tm#HB+Hv p B)X # b i 2 m b?K 2M i Bb QM 27 H 2 K Q  
b C p T`QD2+iX Ai HbQ`2 /BHv bmTTQ`ib 2tTQ`iBM; ;2M2`  
mbBM; i?2 SLJG bkyM/ b/ "(SJL KQ/2Hb- Q` b ;` T?B+ H`2T`2b  
Q7 i?2b2 mbBM; i?2 :` TR p X A 7 Q H K Q p m T T Q ` i b : l A 7 Q ` m b 2`  
HHQr mb2`b iQ bT2+B7v i?2B` BMTmjXp ? Q b 2 p B # 2 V ? B M B 2 + M E  
bmTTQ`i2/ 7Q` i?2 2ti2MbBQM T`QTQb2/ #v i?B B X Q X B - B 2 B H H  
i?2 SG: T`QD2+i- i?2 bQm`+2 +Q/2 Q7 i?2 BKTH2K2Mi iBQM Q  
Bb HbQ Tm#HB X H v ? p B B H 2 # H 2 Q M r B H H K F 2 b 2 p 2 ` H ` 2 7 2 ` 2 M  
+QMi BM2/ BM i?2 BKTH2K2Mi iBQM 7Q` `272`2M+2X  
AM i?2 BKTH2K2Mi iBQM- +2`i BM bBKTHB}+ iBQM b ? p2 #22  
`2/m+2 Bib +QKTH2tBivX 6B`bi Q7 HH- i?2 KQ/2H ;2M2` iQ` /C  
Bib2H7 rBi? / i Q#D2+ibX HbQ- BM Q`/2` iQ #2 #H2 iQ T`2/B  
BM ;2M2` i2/ ; i2r v- HH ; i2r v T ii2`Mb ? p2 #22M b2i iQ H  
#` M+?2bX  
6B;m8XR?Qrb M Qp2`pB2r Q7 i?2 +H bb2b mb2/ iQ BKTH2K  
JQbi bbQ+B iBQM b /Q MQi ? p2 /B`2+iBQM Q` S K i 2 H M B T H B + I  
i?2S ii2`Mq2BM/h ` ;2iq2BX?h?Bb r b /QM2 iQ bi`2bb i? i Bi Bb M  
iQ @QM2 `2H iBQM b?BT-v#MKB+?2M i Q K B x iBQM \* Q M 7 B q m` iB C  
K M 6 ii2` B M bi M+2b bi?2`2 `2 # bB+T ii2`Mb #2BM; mb2/- M  
? b QM2 r2B;?i ii`B#mi2/ iQ Bi- r?B+?h ; ; B M q 2 B b B N b K M i v 2 b

Ra22iiTb,ff;Bi?m#X+QKf M/2`bNjRyfTH;

6B;m`2 8XRQp2`pB2r Q7 i?2 K BM +H bb2b mb2/ BM i?2 BKTH2  
H;Q`Bi?KX

ii +?2/iQ Bi b i?2`2 `2 K2i`B+b bT2+B}2/ b Q#HB; iBQMbX h?2  
i?2b2 +H bb2b Bb `Qm;?Hv 2[mBp H2Mi iQ i?2`AM /BQM MBMQrM  
i?2 `+?Bi2+im`28QR?2mT2BM+BTH2b Q7 HQR +QmTHBM; M/ ?B;?  
#22M mb2/ b ;mB/2HBM2bX h?Bb ? b H2 /iQ /2bB;M i? i ? b [  
T2` +H bbX Ai b?QmH/ ?Qr2p2` #2 MQi2/ i? i i?2 T`Q+2bb Bb +  
72r //BiBQM H +H bb2b i? M r? i i?2 /B ;` K b?Qrb- M/ i?Bb Bb  
Bbbm2X >Qr2p2`- +H2 M M/ mM+Hmii2`S/ Q+2Bkk BQM B; r?2  
`272`2M+2/ r b T`BQ`BiBx2/X

9YzYS BLUI3L3Nj30 /CcjaC\$njCRNc

h?2 T`QTQb2/ ;2M2` iBQM H;Q`Bi?K- \$ 5 2b2MB2/BF2 b? Ti2`  
b2i Q7 Q#HB; iBQMb- r?B+? Bb +QK#BM iBQM Q7 K2i`B+ M/  
HQM; rBi? i?2 T `iB+mH `T`QT2`iB2b Q7 i?2 /Bbi`B#miBQM- bm  
6Q` i?2 BKTH2K2`SiQIBbQM-M /Bb?`B #?2BQM?Qb2M 7Q` HH K2i`  
h?Bb ? b #22M +?Qb2M QM i?2 K2`Bib Q7 Bib bBKTHB+Biv- b T  
iBQM + M #2 bT2+B}2/ #v Bib K2 M- M/ Bib p `B M+2 rBHH #2 i?2  
bQK2r? i 2p2M /Bbi`B#miBQM `2b2K#HBM; MQ`K H /Bbi`B#miBQ

aBM+2 SQBbbQM /Bbi`B#miBQM Bb /Bb+`2i2 T`Q# #BHBiv  
 7Q`p HM XbhB Bb Bb T2`72+iHv bmBi2/ 7Q` K2i`B+bNi?bim HbQ i F2  
 b i?2 MmK#2` Q7 MQ/2b Q` +v+H2bX >Qr2p2`- Bi /Q2b MQi rQ  
 `2 /2}M2/ QminB 22XOX h?2b2 K2i`B+b BM+Hm/2 KQbi QM2b i?  
 b `iBQb- bm+? b i?2 b2[m2MiB HBiv Q` +Q2{+B2Mi Q7 +QM  
 ++QKKQ/ i2 bm+? K2i`B+b- b+ H2/ SQBbbQM /Bbi`B#miBQM  
 SQBbbQM /Bbi`B#miBQM Bbb+ H2//QrM #v 7 +iQ` RyyiQ }i Bi  
 NX 6Q` 2t KTH2- 7Q` /Bbi`B#miBQM 7Q` i?2 b2[m2MiB HBiv Q7  
 Q7 K2 446 rQmH/ #2 +`2 i2/ M/ 2 +? BMi2`p H /BpB/2/ #v Ryy- b  
 rQmH/ #2+QK2 = <sup>46</sup>/<sub>100</sub> =0:46X h?Bb HbQ K2 Mb i? i 2 +? K2i`B+ /2}  
 + M QMHv #2 bT2+B}2/ rBi? ;` MmH `Biv Q7 irQ /2+BK Hb- bm  
 Q7 yXRkj98e rQmH/ QMHv #2 BMi2`T`2i2/ b yXRkX LQi2 i? i M  
 QM i?2 p HB/Biv Q7 b+ HBM; /QrM i?2 SQBbbQM /Bbi`B#miBQM  
 T` +iB+ H r v Q7 bmTTQ`iBM; bm+? K2i`B+bX

9YzYI BLUI3L3Nj jCRN M/Qi KUN, jCRN

h?2 M/QKUM+iBQM /2b+`B 9 XRB BK2H BKQMT2Q BbbQM\_ M/QKU  
 7mM+iBQM M7 QK2 bbX h?2 BKTH2K2Mi iBQM Bb # b2/ QM BMp2  
 THBM;- M/ b bm+? `mMb BM iBK2 T`QTQ`iBQM H iQ i?2 bT2-  
 /Bbi`B#miBQM X h?2 BKTH2K2Mi iBQM ? b #22M # b2/ QM i?2 E  
 BM9X

9YzYk mc3a CNj3a8 ,3

AM //BiBQM iQ Bib mb2` BMi2`7 +2- SG: HbQ Qz2`b +QKK  
 2p2`- MQM2 Q7 i?2b2 BMi2`7 +2b `2 bmTTQ`i2/ #v i?2 BKTH  
 bi i2X AMbi2 /- i?2 2ti2MbBQM + M QMHv #2 `mM #v ++2bb  
 S`Q+2bb:2M2B`iQ+iHv- r?B+? Bb i?2 b K2 b b?QrM B8YX C p 7  
 >Qr2p2`- i?2 /Bz2`2M+2 #2ir22M `mMMBM; i?2 i` /BiBQM Hp2`  
 TQb2/ 2ti2MbBQM- Bb iS`QB-Mbb22/MQ7.vM`KB+S`Q+2bb:2M2`iQ  
 Bb mb2/X h?Bb M2r ivT2 Q7 T`Q+2bb ;2M2`iQ`i F2b /Bz2`2M  
 HQM2- r?B+? `2~2+ib i?2 BMTmi Q7 i?2 T`QTQb2/ 2ti2MbBQM  
 8Xk

aBM+2 i?2 T`QTQb2/ 2ti2MbBQM QMHv bmTTQ`ib SQBbbQM  
 7mHHv /2}M2/ #v bT2+B7vBM;M?K2B+S`Q M2b B 22M2i` HbQ`v QMHv  
 i F2b T B`b Q7 K2i`B+b M/ i?2 /2bB`2/ K2 M p Hm2 Q7 i?2 /B  
 H;Q`Bi?K BMBiB HBx2b i?2 ;2M2`iBQM Q7 T`Q+2bb- i?2b2 T  
 bi?2v `2 /2b+`B #2/ 9Xm # B bTK2` Mb i? ii?2 BKTH2K2Mi iBQM +  
 MQi`2 HBx2 i?2 QM`BiB; Qib`Q7B /2}M2 i?2 +im H BMTM i Q7 H;Q  
 MQi?2` BKTQ`i Mi /Bz2`2M+2 #2 M22M2 BHK`Q H2iK`XMi iBQM Bb  
 i?2`2 /Q2b MQi 2tBbi T`i Q7 i?2 BKTH2K2Mi iBQM i? ii F2b

6B;m`2 8Xk,C p 7` ;K2Mi Q7 i?2 ;2M2` iBQM Q7 b2p2` H T`Q+2b  
i?2 BMi2`7 +2 Q7 i?2 T`QTQb2/ 2ti2MbBQMX LQiB+2 i?2  
T`Q+2bb ;2M2` iQ` 7`QK i?2 QM2 mb2/ BM iBXX p 7` ;K

KQ/2Hb iQ ;2M2` i2X \_ i?2`- i?Bb ? b iQ #2 /QM2 #v ;2M2` iBM;  
.vM KB+S`Q+2bb:KMi2`iBQH2 iBK2b- b B BX Q M2 BM } ;m`2

9YzY: bnUURaj 8Ra K3jaC,c

M BKTQ`i Mi bT2+i Q7 i?2 H;Q`Bi?K Bb i?2 +QM iBMmQmb + H+  
i?2 KQ/2H #2BM; ;2M2` i2/- BM Q`/2` iQ K F2 bm`2 i? ii?2 #2M2}i  
i` ;2i p Hm2bX b bi i2 9 B X K 8V+ KBQ`B +b i? i i?2 ;2M2` iBQM H;Q  
bmTTQ`ib b T`i Q7 i?2 BMTmi Q#HB; iBQM b Kmbi ? p2 Bib QrM K  
2p2`- i?Bb Bb MQii?2 QMHv`2 bQM r?v K2i`B+KB;?i MQi #2 bmT  
b2+i B Q M i?2` 7 +iQ`b HbQ TH v 8 Q M 2 X i ? 2 2 #? B 2 + b  
`2 bmTTQ`i2/ #v i?2 H;Q`Bi?K- M/T`QpB/2 b?Q`i/2b+`BTiBQ  
bmTTQ`i2/- B7 i?Bb Bbi?2 + b2X

JQbi bmTTQ`i2/ K2i`B+b ? p2 + H+mH iQ`b i? i`2 i`BpB H iQ  
bBKTHv +QmMi 2H2K2Mib BM i?2 KQ/2H- Q` ` iBQb #2ir22M bm+?  
Bb KQ`2 +QKTH2t BM i?Bb`2bT2+i Bbi?2 MmK#2` Q7 +v+H2b- bB  
F2Ti` +F Q7 BM i?2 T`Q+2bb KQ/2HX AM Q`/2` iQ 2p Hm i2i?Bb K  
Q7 CQ?MbQMö k 9 H; Q`Bi?K B`/ T`iv Bb mb2/X AM7Q`K iBQM #Q  
T`iv BKTH2K2Mi iBQM Bb BM+Hm/2/ BM i?2 Tm#HB+Hv p BH #  
rQ`FX

A7 i?2`2 bQM 7Q` K2i`B+ MQi #2BM; BKTH2K2Mi2/ Bbi? i Bi B  
bBKTHv K2 Mb i? ii?2 BKTH2K2Mi iBQM ? b #22M /22K2/ Qp2`H  
iQ Qi?2` K2i`B+bX h?Bb Bb Q7i2M i?2 + b2 7Q` +QM i`QH@~Qr`2  
/B K2i2`- r?B+?`2[mB`2 M H;Q`Bi?K i? i + M i F2 i?Bb BMiQ +  
i? i i?B`/ T`iv H;Q`Bi?K rQmH/ ? p2 iQ #2 7QmM/ M/ / Ti2/iQ  
Q` +mbiQK QM2 rQmH/ ? p2 iQ #2 BKTH2K2Mi2/- #Qi? Q7 r?B+? ?  
bB;MB}+ MiHv iBK2 +QMbmKBM;X

a2p2` H Qi?2` K2i`B+b `2 MQi bmTTQ`i2/ /m2 iQ 7` K2rQ`F B  
K2 Mb i? ii?2 /2bB;M2/ H;Q`Bi?K Bb MQi bmBi2/ 7Q` BM+`2K2M

+HQb2` iQ i?2 i `;2i p Hm2 #v mbBM; i?2 T ii2`Mb QX9?2 7` K  
AM Qi?2` rQ`/b- i?2 +QK#BM iBQM Q7 i?2 T ii2`Mb M/ i?2 T`Q  
bmTTQ`ii?2 K2i`B+X h?Bb Bb ?Qr2p2` bi i2/ b 7` K2rQ`F Bb  
BM b2+~~i~~Q M2b2 Bbbm2b + M T`Q# #Hv #2 bQHp2/ #v +? M;BM  
h?2`2 `2 ?Qr2p2` bBim iBQM b r?2`2 i?Bb Bb MQi 2MQm;?- M/  
BKT`Qp2- BM r?B+? i?2 H;Q`Bi?K /2bB;M Bb bi i2/ b i?2 Bbbm

9YzY9 TRcjA2q In jCRN R8 K3jaC,c

AM //BiBQM iQ i?2 `mM@iBK2 + H+mH iBQM Q7 K2i`B+b `2[mB  
+?QQbBM; T ii2`Mb- i?2 BKTH2K2Mi iBQM HbQ BMkH-m/2b M  
++2bbBM; Bib Tm#HB+ SAX h?Bb 2 bBHv HHQrb mb2`b iQ b2  
2tTQ`i2/ KQ/2Hb- M/ Bb r? i rBHH #2 mb2/ iQ Q#iXB M ?22 `2bm  
MmK#2` Q7 K2i`B+b "SJ2i2` bmTTQ`ib Bb ?Qr2p2` HBKBi2/- M  
Q7 i?2 K2i`B+b /?j)M2/ BM (

9YzYf 2uj3NcC\$CICjw N0K CNj CN \$CICjw

1ti2MbB#BHBiv Bb i?2 bT2+i Q7 //BM; M2r 72 im`2b iQ i?2  
+? M;2b iQ i?2 /2bB;M Q` BKTH2K2Mi iBQM- M/ K BMi BM #B  
7Q`KBM; 7mM+iBQM H +? M;2b- M/ i?2 2 b2 Q7 r?B+? i?Bb +  
i?2b2 irQ +QM+2Tib rBHH #2 mb2/ BMi2`+? M;2 #Hv iQ `272` i  
H;Q`Bi?K + M #2 2ti2M/2/ Q` +? M;2/- 7Q` bBKTHB+BivX h?Bb  
+ Mir vb i?2 H;Q`Bi?K Bb 2tT2+i2/ iQ #2 +? M;2/ Q` 2ti2M/2/-  
/Bb+mbb2b BM +M/T?i Bi rQmH/ i F2 iQ BKTH2K2Mi bm+? +? M  
M BKTQ`i Mi T `i Q7 2ti2M/BM; i?2 + T #BHBiB2b Q7 i?2 H  
KQ`2 K2i`B+bX A7 i?2 H;Q`Bi?K + M bmTTQ`ii?2 /2bB`2/ K2i`  
//2/ iQ i?2 bvbi2K #v /2}MBM; p H2i 2B2Q mBk-BM / BKTH2K2MiB  
K2i?Q/ 7Q` + H+mH iBM;J2i`B K2i`H B mXB MQ Bb K2 Mb i? i i?2  
+QKTH2tBiv Q7 //BM; M2r K2i`B+ KQbiHv /2T2M/b QM i?2 B  
+ H+mH iQ`X

M Bbbm2 7Q` bmTTQ`iBM; b2p2` H K2i`B+b Bb i?2 # bB+ T  
};m`PXX a2+iBXM; ;2bib BKTH2K2MiBM; # bB+ T ii2`Mb- Q` +C  
2[mBp H2Mi Q7 i? QbX mb?B/bBrM mH/ }`biHv `2[mB`2 `2/2bB;M  
iQ }M/ i?2 2[mBp H2Mi- M/ rQmH/ HbQ + mb2 +QmTH2 Q7 +  
6B`bi Q7 HH- i?2 `2+m`bBp2M2bb Q7 i?2 ;2M2` iBQM 7` K2rQ`  
iQ KQ`2 Bi2` iBp2 QM2X JQ`2 bT2+B}+ BHQ+2B b2M2`MibQ i? i  
rQmH/ MQ HQM;2` ;2M2` i2 QM2 bBM;H2 T ii2`M `2+m`bBp2Hv  
7Q` TH +2?QH/2`b Qp2` M/ Qp2`- #mirQmH/ ? p2 iQ Bi2` iBp2  
`mH2b iQ i?2 KQ/2HX HbQ- i?2 7` K2rQ`F rQmH/ M22/ r v Q7 /  
2 +? +QMbi`m+iBQM `mH2X q? i FBM/ Q7 b+?2K2 iQ mb2 Bb K  
M BKTH2K2Mi iBQM Bbbm2- #mi Bi b?QmH/ #2 TQbbB#H2 iQ +  
i? i Bi Bb MQi /2T2M/2Mi QM Mv Qi?2` T SiQ Q2bi?2 M2bi2Q`i? M

MQi?2` bm;;2bi2/ BKT`Qp2K2Mi Bb iQ `2/2bB;M i?2 H;Q`Bi?H  
 #2M2}i Q7 +?QqbBM; T ii2`Mb- iQ QM2 i? i Bb + T #H2 Q7 HQQF  
 i?2 ;2M2` iBQM- BX2X Bb KQ`2 +H2p2`X h?2 BKTH2K2Mi iBQM C  
 #H2 iQ #2 +QMi B`2W2F`BHi ?2- Q` iQ QMHv #2 /2T2M/2Mi QM i?B  
 BM7Q`K iBQM +QMi BM2/ i?2`2X  
 b bi i2/ BM B`2W2F`BHi ?2- Q` iQ QMHv #2 /2T2M/2Mi QM i?B  
 /2MbBiv K2i`B+ 7`QK #2BM; BKTH2K2Mi2/X h?Bb Bb`2H i2/iQ i?  
 i?2 #2M2}i- r?2`2` /BbiBM+iBQM Bb K /2 #2ir22M KQMqiQMB+  
 M/ K2i`B+b i? i `2 MQi M2+2bb `BHv i?Bb- M K2Hv` iBQ@# b2  
 i? i Bi Bb`2;`/BM; Mv` iBQ@# b2/ K2i`B+ UQ` `RM?2b Mv K2i`  
 MQM@KQMqiQMB+X >Qr2p2`- 7Q` i?2 /2MbBiv K2i`B+- i?Bb Bb M  
 KQ/2H bBx2b- b Bi Bb KQMqiQMB+ HHv /2+`2 bBM; 7Q` #B;;2` Q  
 +`2 i2 M2r`mH2b r?2M + H+mH iBM; i?2 #2M2}i i? i `2 ;2M2` H 7

### 9YzYe T3a8RaL N,3

h?2 +im H`mMMBM; iBK2 Q7 i?2 H;Q`Bi?H  
 b?QrM i? i i?2`mMMBM; iBK2 Bb ?B;?Hv /2T2M/2Mi QM i?2 bBx2 C  
 q?BH2 BKT`QpBM; i?Bb /2T2M/2M+v- Q` +? M;BM; i?2 iBK2 +QKT  
 BM ;2M2` H- `2[mB`2b `2/2bB;M Q7 i?2 H;Q`Bi?K- i?2`2 `2 +2`  
 + M #2`2 /BHv K /2 iQ`2/m+2 i?2`mMMBM; iBK2X  
 h?2 KQbi Q#pBQmb QTibKBx iBQM- M/ i?2 QMHv QM2 i? i rBH  
 `2/m+BM; i?2 iBK2 i?2 H;Q`Bi?K bT2M/b + H+mH iBM; i?2 K2i`B  
 ;2M2` i2/X "v /2#m;;BM; i?2 H;Q`Bi?K- Bi Bb TQbbB#H2 iQ b?Q  
 2p Hm i2/ r? QrTtyBi`K`2b 2 +? M2r T ii2`M i? i Bb ;2M2` i2/X A/2  
 H;Q`Bi?K b?QmH/ QMHv + H+mH i2 2 +? K2i`B+ 7Q` i?2 KQ/2H  
 T ii2`M- BM Q`/2` iQ T`2/B+i i?2 p Hm2 Q7 i?2 K2i`B+ B7 i?2 T ii  
 iBK2 M2r T ii2`M Bb +?Qb2MX h?Bb rQmH/ // mT iQ B/2 HHv + H  
 iBK2b+? iBK2 M2r T ii2`M Bb +?Qb2M- r?B+? Bb j9 iBK2b H2bb i?  
 Q7 iBK2bX h?2`2 bQM r?v i?Bb Bb MQi i?2 + b2 Bb K BMHv /m2 iQ  
 i?2 p Hm2 Q7 K2i`B+ Bb`2 / i Mv TQBmi /m`BM; 2t2+miBQM- B  
 HH Qp2` ; BMX h?Bb K2 Mb i? i 2p2`v iBK2 Bi Bb HQ;;2/- Q` 2p  
 MQi?2` +H bb- Bi ? b iQ #2`2+ H+mH i2/X >Qr2p2`- i?Bb + M #  
 + +?BM; bQHmiBQMS BM + 2`B+??b?2? 2 p Hm2b Q7 Bib QrM K2i`B-  
 BMp HB/ i2b i?Bb + +?2 r?2M2p2` +? M;2 iQ Bi ? TT2Mb- r?B+?  
 T ii2`M Bb //2/X

J2i`B+	Ab b m T @ bQM TQ`i2/		*QKK2Mi
LmK#2` MQ/2b	Qz b		
LmK#2` Q7 BiB2b	uiBp @		
LmK#2` Q7 r vb	; ui2b@		
LmK#2` L.@; i2r vb	Qz b		
LmK#2` sP_@; i2r vb	Qz b		
.B K2i2`	LQ UMQi Q`BiBx2/V	T`B@`BQ`Bi	Bx2/#2 b mTTQ`i2/- #mi r b MQi T`BQ`BiBx2/ /m2 iQ BKTH2K2Mi iBQM +QKTH2 BivX
.2MbBiv	LQ	AKTH2K2Mi Bbbm2	iBQM2 b mTTQ`i2/ #v i?2 H;Q`Bi?K- #mi MQi #v i?2 +m``2Mi BKTH2K2Mi iBQM BiX h?Bb Bb #2+ mb2 i?2 K2i`B+ Bb KQM QiQMB+ H /2+`2 bBM; r?2M i?2 MmK@ #2` Q7 MQ/2b ;2ip #Qp2 +2`i BM p Hm2- M/Bb MB TH2K2Mi iBQM Bbbm2X
*Q2{+B2Mi +QMM2+iBp	aQK2r? i Biv	6` K2rQ`F Bbbm2	h?2 H;Q`Bi?K T`QpB/2b bQK2 b mTTQ`i- #mi i?2 K2i`B+ + M 2 bBHv 2Mi2 B MiQ HQ+ H K tBKmKX h?Bb Bb SG: 7` K2rQ`F Bbbm2- `2H i2/ iQ i?2 T i i2`Mb mb2/X
p2` ;2 /2; Q7 ; i2r vb	LQ	6` K2rQ`F Bbbm2	* M #2 b mTTQ`i2/- #mi /m2 iQ bBKTHB}+ iBQM b i i?2 ;2M2` iBQM 7` K2rQ`F- i?2 QMHv Qmi@/2;`22 Q ; i2r v TQbbB#H2 Bb k- r?B+? K F2b i?2 p2` ;2 /2;`22 RX8 7Q` HH }MBb? KQ/2HbX
J tBKmK /2LQ ;`22 Q7 ; i2r vb	LQ	6` K2rQ`F Bbbm2	* M #2 b mTTQ`i2/- #mi /m2 iQ bBKTHB}+ iBQM b i i?2 ;2M2` iBQM 7` K2rQ`F- i?2 QMHv Qmi@/2;`22 Q7 ; i2r v TQbbB#H2 Bb kX

h #H2 8Xm,Qp2`pB2r Q7 r?B+? K2jiBx2bQ7TitQH2/ #v i?2 +m``2  
BKTH2K2Mi iBQM Q7 i?2 H;Q`Bi?KX

J2i`B+	Ab b m T @ b Q M T Q `i2/	* Q K K 2 M i	
a2T ` #BH	B L Q	L Q i T ` B Q ` B i B x 2 / # 2 b m T T Q ` i 2 / - # m i r b M Q i T ` B Q ` B i B x 2 / / m 2 i Q B K T H K 2 M i i B Q M + Q K T H 2 t B i v X	
a2[m2MiB	H a B Q K 2 r ?	i 6 ` K 2 r Q ` F M / H ; Q ` B i ? K ` i b B M + 2 B M + ` 2 b B M ; Q ` / 2 / 2 b B ; M B b b m + 2 2 b B M ; i ? 2 K 2 i ` B + Q 7 i 2 M ` 2 [ m B ` 2 b # b B + T i i 2 ` M 7 Q H @ H Q r 2 / # v M + i B p B i v i Q B M @ + ` 2 b 2 Q ` / 2 + ` 2 b 2 - r ? B + ? K 2 M b i ? i i ? 2 H ; Q ` B i ? K Q 7 @ i 2 M + M M Q i M i B + B T i 2 ? Q r i Q + ? M ; 2 i ? 2 p H m 2 Q 7 i ? 2 K 2 i @ ` B + X h ? B b K 2 M b i ? i i ? 2 H @ ; Q ` B i ? K r B H H Q 7 i 2 M 2 M i 2 ` B M M 2 M / H 2 b b H Q Q T - M / B b T ` Q H 2 K ` 2 H i 2 / i Q + Q K # B M i B Q M Q 7 i ? 2 p B H # H 2 T i i 2 ` M b - M / i ? 2 + H 2 p 2 ` M 2 b b Q 7 / 2 + B / B M ; i K 2 i ` B + # 2 M 2 } i Q 7 T i i 2 ` M b X	
ai`m+im`2	M L Q b b	6 ` K 2 r Q ` F B b b m 2	L Q i b m T T Q ` i 2 / b i ? 2 7 ` K 2 @ r Q ` F T i i 2 ` M b Q M H v b m T T Q ` i b i ` m + i m ` 2 / # H Q + F b - r ? B + ? K 2 M b i ? i i ? B b K 2 i ` B + r Q m H / Q M H v 2 p 2 ` i F 2 p H m 2 Q 7 R - b B M + 2 B i B b 7 m H H v b i ` m + i m ` 2
.2Ti?	LQ	L Q i T ` B Q ` B i B x 2 / # 2 b m T T Q ` i 2 / - # m i r b M Q i T ` B Q ` B i B x 2 / / m 2 i Q B K T H K 2 M i i B Q M + Q K T H 2 t B i v X	
*QMM2+iQ` K i+?	L K B b @	6 ` K 2 r Q ` F B b b m 2	a B M + 2 i ? 2 7 ` K 2 r Q ` F Q M H v b m T T Q ` i b # H Q + F @ b i ` m + i m ` 2 / K Q / 2 H b - H H + Q M M 2 + i Q ` b r B H H H # 2 K i + ? 2 / - M / i ? 2 + Q M M 2 + @ i Q ` K B b K i + ? r Q m H / i ? 2 ` 2 7 Q ` 2 Q M H v 2 p 2 ` i F 2 i ? 2 p H m 2 y X
*QMM2+iQ` 2`Q;2M2Biv	u 2 2 i @		
*QMi`QH +QKTH2tBiv	u Q b		
LmK#2`Q7 +H2b	u 2 2 b @		
hQF2M bTH	B i 2 b		

h #H2 8XM, Qp2`pB2r Q7 r?B+? K2jiXB+2bQ7TiT@H22/ #v i?2 +m``2Mi  
BKTH2K2Mi iBQM Q7 i?2 H;Q`Bi?KX



J2i`B+	* H+mH iQ` iBK2 +QKTH2tBiB2b
LmK#2` Q7 MQ/2b	PURV
LmK#2` Q7 +iBpBi	PURV
LmK#2` Q7 ; i2r vb	PURV
LmK#2` Q7 L.@;	PURV
LmK#2` Q7 sP_@;	PURV
* QMM2+iQ` ?2i2` QP	N2 Bb i?2 MmK#2` Q7 ; i2r vb BM i?2 KQ/2H
* QMi`QH ~Qr +QK	N2 Bb i?2 MmK#2` Q7 ; i2r vb BM i?2 KQ/2H
LmK#2` Q7 +v+H2b	logsV- r?2` Bb i?2 bBx2 Q7 i?2 KQ/2H #2BM; 2p Hm i2/X CQ?MbkMbb H;Q`Bi? #2BM; mb2/X
hQF2M bTHBi	N2 Bb i?2 MmK#2` Q7 ; i2r vb BM i?2 KQ/2H

h #H2 8Xj?,2 iBK2 +QKTH2tBiB2b Q7 i?2 BKTH2K2Mi2/ K2i`E

h?Bb T ;2 ? b #22M BMi2MiBQM HHv H27i #H MF

+ ? Ti2`f

`3cnljc N0 /Cc,nc

h?2 7QHHRBM; b2+iBQM b/Bb+mbb i?2 /Bz2`2Mi bT2+ib Q7 i  
b?Q`i+QKBM;bX h?2 7QHHRBM; bT2+ib rBHH #2 BM 7Q+mbX

Ç \*Q`2+iM2bb

Ç .Bp2`bBiv

Ç \_mMMBM; iBK2

Ç amTTQ`i 7Q` K2i`B+b

fYS +Raa3,jN3cc

h?Bb b2+iBQM b22Fb iQ b?Qr i?2 +Q`2+iM2bb Q7 i?2 H;Q`Bi  
;2M2` i2/ KQ/2Hb ?Bii?2B`i`;2i p Hm2b- br2HH bi?2 /Bbi`B  
i?2 ;2M2` i2/ KQ/2H +QHH2+iBQMX A7 bbmKBM; i? i T`QT2`  
2Mbm`2/ B7 i?2 H;Q`Bi?K ?Bib i?2 i`;2i p Hm2b 7Q`2 +? KQ/  
i?2 +Q`2+iM2bb Q7 i?2 QH;Q`Bi?K ?Bib i?2 i H;Q`Bi?K ?Bib i?2 i  
h?Bb K2 Mbi? i B7 i?2`2 2tBbib bQHmiBQM 7Q`r?B+? i?2 ;2M2`  
p Hm2b- i?2M i?2 H;Q`Bi?K b?QmH/ ;2M2` i2 bm+? bQHmiBQ  
h?2 7QHHRBM; bm#b2+iBQM b +QMi BMb i2bib 7Q` /Bz2`2M  
/2bB;M2/ iQ b?Qr i?2 K2`Bib M/ b?Q`i+QKBM;b Q7 i?2 H;Q`Bi  
K2i`B+bX ae2+rBQM mbb2b i?2 BKTHB+ iBQM b Q7 i?2 b?Q`i+QK  
M/ T`QTQb2b TQbbB#H2 bQHmiBQM b 7Q`2 +? Q7 i?2KX

fYSYS KRNRjRNC, K3jaC,c

h?2 bBKTH2bi K2i`B+b iQ ? M/H2 7Q` i?2 H;Q`Bi?K b?QmH/ #2  
K2i`B+b- r?B+? mbm HHv +Q2-M2n7Q`K Q72 MmK#2` Q7 +iBpB  
MmK#2` Q7 ; i2r vbX AM Q`/2` iQ /2i2`KBM2 i?2 +Q`2+iM2bb C  
`2H iBp2Hv bBKTH2 K2i`B+b- i2bi rBi? i?`22 KQMqiQMB+ K2  
i?2 H;Q`Bi?K 7Q` i?Bb i2bi + M`X2 b22M BM i #H2  
LQM2 Q7 K2i`B+b mb2/ b BMTmi 7Q` i?Bb i2bi ? p2 Mv BM?  
/Q- ?Qr2p2`- ? p2 bQK2 /2T2M/2M+v BM i2`Kb Q7 i?2 TQbbB#H  
+ M T`Q/m+2X h?Bb Bb #2+ mb2 k +iBpBiB2b `2 Hr vb +`2 i2/

h #H2 eXR;Q`Bi?K BMTmi rBi? KQMqiQMB+ K2i`B+bX  
 aBx2 Q7 +QHHR2yiBQM,  
 P#HB; iBQMb,

J2i`B+	J2 M p Hm2QMqiQMB+
LmK#2` Q7 L.@; R2yb	u2b
LmK#2` Q7 sP_@; Ri2b	u2b
LmK#2` Q7 +iBp Bj2b	u2b

sP\_@; i2r vbi?`Qm;? 2Bi?2` T ` HH2H 2t2+miBQM- Kmim H 2t+  
 h?Bb K2 Mbi? ii?2 MmK#2` Q7 +iBpBiB2b Bb Hr vb2[m HiQ- Q`  
 Q7 L.@ M/ sP\_@; i2b- MmK#2` Q7 +iBpBiB2b Q7 L.+@; i2b  
 MmK#2` Q7 sPX @; i2b ? Qr2p2` Hr vb TQbbB#H2 7Q` i?2 H;Q`B  
 T2`72+ibQHmiBQM 7Q` i?2 MmK#2` Q7 +iBpBiB2b- ;Bp2Mi? i#Q  
 M/ MmK#2` Q7 sP\_@; i2b ? p2 ?Bi i?2B` i `;2i p Hm2- M/ i?2 M  
 ? b MQi v2i- #v +`2 iBM; b2[m2M+2 M/ +iBpBiv T ii2`M ;Bp2M  
 Qi?2` rQ`/b- i?2`2 2tBbib iH2 biQM2 bQHmiBQM r?2`2 HH i?`22  
 QM2 Q7 r?B+? i?2 H;Q`Bi?K b?QmH/ +?QQb2X

h #H2 eX2, b m Hib Q7 i?2 BMeTxi BM i #H2

J2i`B+	J2 M p2` ;2 #bQHmi2 /Bbi M+2 iQ i` ;2i
LmK#2` Q7 L.@ N23y	yXeR UeXk WV
LmK#2` Q7 sP_@Ryi2Bey	Xdd UdXe WV
LmK#2` Q7 +iBpBiB2B9	XeN URd WV

GQQFBM; ii?2 `2bm+XbBBBb #H2 #H2 i? ii?2 H;Q`Bi?K ?Bi  
 i` ;2i r2HH 7Q` MmK#2` Q7 L.@; i2b M/ MmK#2` Q7 sP\_@; i2bX  
 H;Q`Bi?K + M #2 +QMbB/2`2/ 2p2M #2ii2`- r?2M i FBM; BmiQ +  
 p Hm2 + M i F2 QM Q// p Hm2b- r?BH2 ; i2r vb `2 Hr vb ;2M2` i  
 bm+? i? i Bi Bb BKTQbbB#H2 iQ ;2M2` i2 KQ/2H rBi? M Q// MmK  
 q?BH2 i?2 `2bmHib 7Q` i?2 MmK#2` Q7 +iBpBiB2b `2 MQi T `  
 rQ`b2i? M 7Q` i?2 Qi?2` irQ K2i`B+bX h?2 ++m` +v Q7 i?2 H;Q`B  
 i? i Bi KBbb2b i?2 i `;27%p QHm2 #v ;2X LQiBM; i? i Bi KQbi Q7i2M  
 p Hm2 HQR2` i? Mi?2 i `;2i p Hm2- M/ +QMbB/2`BM; i? ii?2`2 Bb  
 K F2b i?2 KQ/2H`2 +? Q` bm`T bbi?2 i `;2i p Hm2 7Q` i?2 MmK#2`  
 `2bmHib `2 MQi QTiBK HX

fYSYI KRNRjRNC, N0 MRNALRNRjRNC, K3jaC,c

q?BH2 KQbi KQMqiQMB+ HHv BM+`2 bBM; K2i`B+b `2 7 B`Hv bE  
 M2+2bb `BHv i?2 + b2 7Q` MQM@KQMqiQMB+ K2i`B+bX h?2 +?

+ M #Qi? BM+`2 b2 M / /2+`2 b2- M / K v HbQ +QM i BM HQ+ H  
 i?2 BMBiB H p Hm2 iQ i?2 i `;2i p Hm2X hQ i2bi i?2 +Q``2+iM2b  
 K2i`B+b BM +QMDmM+iBQM rBi? KQM QiQMB+ QM eX? bi2bi rBi  
 #22M /2pBb2/X

h #H2 eXh;Q`Bi?K BMTmi7Q` KBtQ7 #Qi? KQM QiQMB+ M / MG

aBx2 Q7 +QH H2y iBQM,  
 P#HB; iBQM b,

J2i`B+	J2 M p Hm2QM QiQMB+
LmK#2` Q7 LQ/2b	9y u2b
*QM i`QH 6HQr *Q	KRTyH2tBiv u2b
*QMM2+iQ` >2i2`	Qy;2d/82 Biv LQ

b + M #2 b22M 7`eQMM QM2 Q7 i?2 K2i`B+b mb2/ ?Bi i?2 /2bB`  
 +HQb2bi QM2 #2BM; i?2 +QMM2+iQ` ?2i2`Q;2M2Biv- r?B+? T`  
 K2 M p Hm2Q7 i?2 /2bB`2/ K2 MX Aib p2` ;2 /Bz2`2M+2 iQ  
 7Q` 2 +? + b 2:6%- Q MB+? B i:Q T2H+2Mi ;2 TQBMib #Qp2 i?2 iQH  
 i?2 ;2M2` iBQM +HQ2B+?K Uh `;2iBiVi2/ BM b2XRB QMK i #H2  
 eX9?2 p `B M+2 Q7 i?2 /Bbi`B#miBQM Bb bB;MB}+ MiHv HQr2`  
 Q7` SQBbbQM /Bbi`B#miBQM- r?B+? Bbi?2 b K2 bi?2 K2 MX  
 };m`2XkU#?B+? b?Qrb i? i i?2 b? T2 Q7 i?2 /Bbi`B#miBQM Bb  
 `272`2M+2 SQBbbQM /Bbi`B#miBQM X

6Q` i?2 MmK#2` Q7 MQ/2b M / \*6\*- r?BH2 i?2 p `B M+2 Q7 i?  
 2tT2+i2/ p Hm2 7Q` i?2 +QMM2+iQ` ?2i2`Q;2M2Biv- Bi Bb 2pB  
 bm#bi MiB HHv Qz i?2 K `FX \*QKT `2/ iQ i?2 ;Q H Q7 ?BiiBM; i  
 K2i`B+ 2p2`v iBK2- M p2` 122/ BM 20:2MB2 Q7 `;2 Qzb2iX Ai b?Q  
 HbQ #2 MQi2/ i? i i?2 +QM i`QH ~Qr +QKTH2tBiv mbm HHv ?B  
 i `;2i p Hm2- r?BH2 i?2 QTTQbBi2 Bb i`m2 7Q` i?2 MmK#2` Q7

h #H2 eX2bmHib Q7 i?2 BMeTxi BM i #H2

J2i`B+	J2 M o `B M+2	p2` ;2 #bQHmi2 7Bbi M+2 iQ i `;2i
LmK#2` Q7 MQ/2b	jdXd383X9N	8Xkd URjXk W V
*QM i`QH 6HQr *Q	KRTyH2tBiv	kXyR UkyXR W V
*QMM2+iQ` >2i2`	Qy;2d/82 Biv	yXy8R UeXe W V

fYSYk /Cc,nccCRN R8`3cnljc

b + M #2 b22M 7`eQMM QM2 Q7 i?2 K2i`B+b mb2/ ?Bi i?2 /2bB`  
 Bb 7 B`Hv ;QQ/- i?2`2 Bb biBHH`QQK 7Q` BKT`Qp2K2MibX h?E  
 iQ }M/ i?2 T`Q# #H2 + mb2b Q7 Bib b?Q`i+QKBM;b- M / T`QTQ  
 i?2KX

6B;m`2 e.XB,i`B#miBQM Q7 i?2 K2i`B+b BM i?2 +QH2+iBQM ;2M  
Q7 i #eX

U VmK#2` Q7 MQ/2b

U#VQMi`QH 6HQR \*QKTH2tBiv

U+VQMM2+iQ` >2i2`Q;2M2Biv

fYSYkYS i3aLCN jCRN R8 ;3N3a jCRN

AM i?2 i2bi Q7eX2+iBQM;Q`Bi?K Bb b?QrMiQ ?Bii?2 i` ;2i p Hm2  
7Q` i?2 irQ K2i`B+b`2; `/BM;i?2 MmK#2` Q7 ; i2r vb- #mi/Q2b M  
MmK#2` Q7 +iBpBiB2b- r?B+? QM p2` ;2 ?Bib p Hm2 kX9N HQR  
aBM+2 i?2 H;Q`Bi?K b?QmH/ #2 #H2 iQ ?Bii?2 i` ;2i p Hm2 7Q` i  
#v +`2 iBM; +QMb2+miBp2 b2[m2M+2 M/ +iBpBiv T ii2`Mb- bQ  
QTiBK HHv BM i?2 H;Q`Bi?KX A7- BM i?2 bBim iBQM r?2`2 i?2 M  
?Bii?2 i` ;2i p Hm2 v2i- i?2 H;Q`Bi?K M2p2` biQTT2/- i?2 H;Q`B  
`2 +? i?2 i` ;2i p Hm2X h?Bb Bb #2+ mb2 M2Bi?2` i?2 b2[m2M+2 i  
`2 /Bb /p Mi ;2Qmb 7Q` Mv Q7 i?2 K2i`B+b- bQ i? i B7 i?2 H;Q  
i?2b2 rQmH/ 2p2Mim HHv #2 +?Qb2MX h?Bb BM/B+ i2bi? i i?2 M  
aBM+2 i?2 i2`KBM iBQM Q7 i?2 ;2M2` iBQM Q7 2 +? KQ/2H Bb +QM  
#2M2}i T `i Q7 i?2 iQi H #2M2}i- i?Bb Bb HBF2Hv r?2`2 i?2 T`Q#H  
AM/22/ i?2`2 Bb b?Q`i+QKBM; BM r? i +QMi`QHb i?2 i2`KBM i  
aBM+2 i?Bb Bb ;2M2` i2/ b T `i Q7 i?2 #2M2}i- i?2 H;Q`Bi?K Dmb  
Q7 biQTTBM; 7`QK 2 +? Q7 i?2 K2i`B+ i` ;2i p Hm2b- BMbi2 / Q7  
Q7 r?2i?2` BirQmH/ +im HHv #2 /p Mi ;2Qmb iQ biQT i?2 ;2M2  
KQ/2HX 6Q` i?2 + b2 Q7 i?2 eX2+iBQM TT2Mb Bb i? i i?2 i

K2i`B+b 7Q`i?2 MmK#2` Q7 ; i2r vb ?Bi i?2B`i` ;2i p Hm2 #270  
aBM+2 i?2v ? p2 MQR`2 +?2/ i?2B`i` ;2i p Hm2- i?2B`iQi H #  
H;Q`Bi?K b?QmH/ biQT- r?BH2 i?2 #2M2}ib + H+mH i2/ 7Q` Mn  
>Qr2p2`- bBM+2 i?2`2 `2 MQR irQ K2i`B+b i? i r Mi i?2 ;2M2`  
QM2 i? i /Q2b MQi- i?2 H;Q`Bi?K Bb ;QBM; iQ 7 pQm` T ii2`Mb  
Q7 TH +2?QH/2`b BM i?2 KQ/2H iQr` / y- biQTTBM; i?2 ;2M2` i  
biBHH K2i`B+ 7Q`r?B+? i?2 i` ;2i p Hm2 + M #2`2 +?2/X AM Q  
? b M Bbbm2 rBi? biQTTBM; i i?2 QT iBK H iBK2X  
AM Q`/2` iQ biQT i KQ`2 QT iBK H TQB Mi Q7 i?2 ;2M2` iBQ  
iQ HQQF i i?2 +QHH2+iBp2 #2M2}i Q7 biQTTBM; i?2 ;2M2` iB  
+ M #2 /QM2 #v HQQFBM; i i?2 p2` ;2`2H iBp2 /Bbi M+2 iQ  
K2i`B+b 7`QK ;2M2` iBM; 2 +? T ii2`MX A7 MQ T ii2`Mb `2 +QM  
i?2 p2` ;2 /Bbi M+2 iQ HH i` ;2i p Hm2b- i?2 H;Q`Bi?K HBF2H  
bQHmiBQM- M/ b?QmH/ biQT ;2M2` iBQM- #v +QMp2`iBM; HH  
;2M2` i2/ KQ/2H iQ bFBT T ii2`MbX

fYSYkYI HR, I K uCL

q?2M /2 HBM; rBi? MQM@KQM Qi QMB+ K2i`B+b- i?2`2 Bb `B  
+ m ;?i BM HQ+ H K tBKmK BM i2`Kb Q7 i?2 #2M2}iX h?Bb + M  
iQ ;2M2` i2 bQHmiBQM r?2`2 i?2 K2i`B+ ?Bib Bib i` ;2i p Hm  
Mv #2M2}i 7Q` i?2 K2i`B+ i i?2 +m`2Mi TQB Mi Q7 ;2M2` iBQM  
H;Q`Bi?K + M ;2i bim+F i`vBM; iQ`2 +? i?2 i` ;2i p Hm2- #mi M  
iQ +?QQb2 iQ ;2i i?2`2X  
PM2 2t KTH2 Q7 bm+? bBim iBQM Bb 7Q` i?2 b2[m2MiB HBi  
Q7 i?2 MmK#2` Q7 +QMM2+iBQM b #2ir22M MQM@; i2r v MQ/2  
+QMM2+iBQM bX AM Q`/2` iQ BM+`2 b2 i?Bb` iBQ- i?2 H;Q`Bi  
T ii2`M i? i + M MQi +QMM2+i iQ ; i2r vX q?BH2 i?Bb Bb mb  
? TT2M i? i HH`2K BMBM; 2KTiv T ii2`Mb BM i?2 ;2M2` iBM; H  
; i2r vb- bm+? b<sup>empty</sup>. c L.ôX :2M2` iBM; M +iBpBiv T ii2`M B  
i?2 2KTiv T ii2`M rQmH/ MQi BM+`2 b2 i?2` iBQ- #mi/2+`2 b2 B  
? b iQ ;2M2` i2 KQ`2 i? M irQ b2[m2M+2 T ii2`Mb- M/ i?2M +i  
i?2B` 2KTiv T ii2`MbX >Qr2p2`- bBM+2 i?2 H;Q`Bi?K QMhv H  
/Q2b MQi FMQR i?Bb- M/ rBHH 2 bBHv #2 bim+F BM HQQT Q7  
T ii2`Mb- bBM+2 M2Bi?2` Q7 i?2b2 /2+`2 b2 i?2 p Hm2 Q7 i?2  
bim+F BM HQ+ H K tBKmKX  
h?Bb b?Q`i+QKBM; + M #2 bQH p2/ #v B Mi`Q/m+BM; bK`i2`  
i?2 #2M2}i Q7 +?QQbBM; M2r T ii2`Mb- r?B+? rQmH/ ? p2 iQ  
ôKQp2bô ?2 /X TQbbB#H2 bQHmiBQM i? i bT`BM; b iQ KBM/ r  
T ii2`M b T2`7Q`KBM; KQp2- Bb QM2 #Q``QrBM; BMbTB` iBQ  
(d)X h?2 +QKKQM HBiB2b #2ir22M i?2 ;2M2` iBQM H;Q`Bi?K ?  
Bb i? i #Qi? ? p2 iQ HQQF b2p2` H KQp2b ?2 /- M/ i F2 H` ;  
Qmi+QK2b B MiQ ++QmMi- r?B+? `2/2i2`KBM2/ BM biQ+? biB  
`2 HbQ TQbbB#H2- #mi T`QTQbBM; bT2+B}+ bQHmiBQM Bb

fYSYkYk BLURccC\$I3 K3jaC, p ln3c

HH K2i`B+b `2 QMHv /2}M2/ 7Q` +2`i BM b2i Q7 p Hm2bX 6Q`  
MQ/2b BM KQ/2H Bb`2bi`B+i2/ iQNiX 2GNB F2r`B b2M in?2#22pm2MiB H  
+ M QMHv i F2 [Q1]Hm@CBM?2 b2i Q7 T ii2`Mb mb2/ BM SG:- i?2 +  
?2i2`Q;2M2Biv + M QMHv i F2 [Q1]Hm@CBM?2 b2i Q7 T ii2`Mb mb2/ BM SG:- i?2 +  
r?2`2 i?2`2 `2 MQ Q++m`2M+2b Q7 KQ/2Hb rBi? p Hm2b QmibB/2  
i?2 b+ H2/ SQBbbQM/Bbi`B#miBQM rBi? K2 MQ7 yXd8 i? i Bb mb  
Bb /2}M2/ QmibB/2 i?Bb` M;2X

6BtBM; i?Bb b?Q`i+QKBM; rQmH/ MQi i F2 K DQ` `2/2bB;M Q  
` i?2`2Mi BHb i?2 H;Q`Bi?K? pBM; i?2/2}M2/` M;2 Q7 HH K2i`  
MQi iQ b2i i` ;2i p Hm2b QmibB/2 i?2b2` M;2bX

fYSYkY: 2LUjw T jj3aNc

MQi?2` b?Q`i+QKBM; Q7 i?2 H;Q`Bi?K Bb Bib mb2 Q7 2KTiv T  
M/ i?2B` BMi2`T`2i iBQM b 2KTiv bi`BM; bX h?Bb mbm HHv K M  
7Q` +2`i BM K2i`B+b r?2M + H+mH iBM; i?2 #2M2}i Q7 ;2M2` iB  
TH +2?QH/2`b- bBM+2 i?2 T ii2`Mb `2 M2+2bb `v 7Q` BM+`2 bBM  
#mi ;2M2` iBM; bm+? T ii2`M rBi? 2KTiv bi`BM; b BMbi2 / Q7 +ir  
MQi z2+i i?2 K2i`B+X PM2 2t KTH2 Bb ;2M2` iBM; b2[m2M+2 T  
K2i`B+- r?B+?- KQM; Qi?2` T ii2`Mb- Bb M2+2bb `v 7Q` BM+`2 b  
i?2 KQ/2HX >Qr2p2`- r?2M i?2 M2r TH +2?QH/2` Bb BMi2`T`2i2/  
i?2 T ii2`M /Q2b MQi +im HHv //iQi?2 H2M; i? Q7 p`22 T i?- bBM+  
c +QKTQM 2M iQ KKTQM2Mi c +QKTQM2MiôX h?Bb Bb <sup>Permpy</sup> HbQ i?2 + b2 7  
QM M +im H +QKTQM2Mi iQ #2 ;2M2` i2/ BM 2 +? Q7 i?2 #` M+?2  
#27Q`2 i?2B` 2z2+i + M #2 b22MX PM2 bm+? K2i`B+ Bbi?2 p2` ;2  
i?2/2;`22 Q7 2 +? ; i2r v @bTHBi rBHH #2 R B7 i?2`2 `2 QMHv TH  
M/ i?2 MmK#2` Q7 #` M+?2b B7 HH TH +2?QH/2`b r2`2`2TH +2/

PM2 bQHmiBQM iQi?Bb T`Q#H2K +QmH/ #2 iQ BMi`Q/m+2 k  
/m`BM; i?2 + H+mH iBQM Q7 i?2 #2M2}i- bm+? i? i Bi HQQFb b2  
i?2 bBKmH iBQM- HBF2 T`QX rX pXkBM b r2m BQ MHHQr i?2 H;Q`B  
iQ T`2/B+i i?2 #2M2}i 7Q` 2 +? K2i`B+- M HQ;Qmb iQ T`2/B+iB  
HQ+ H K tBK X MQi?2` bQHmiBQM rQmH/ #2 iQ +? M;2 i?2 7` H  
;2M2` iBM; TH +2?QH/2`b HiQ;2i?2`- M/ BMbi2 / Dmbi;2M2` i  
i?2b2 b TH +2?QH/2`b BMbi2 /X am+? b+?2K2 rQmH/ bi`i iQ H  
mb2/ Bm (r?2`2 i?2v /2}M2+2M2iQm+iBiQM i?2H2T THv iQi?2 KQ/2H  
iQ i` Mb7Q`K BiX AM bm+? b+?2K2- bBM+2 MQ T`ib Q7 i?2 KQ/2  
i?2 2KTiv T ii2`M i Mv iBK2- i?2 T`Q#H2K Q7 TH +2?QH/2`b Bb  
rQ`i? MQiBM; i? i B7 K2i`B+ biBHH`2[mB`2b +2`i BM b2`B2b  
bK`i2` HQQF@ ?2 / H;Q`Bi?K 7Q` /2i2`KBMBM; i?2 #2M2}i Bb M



# fYI /Cq3acCjw

AM //BiBQM iQ ? pBM; i?2 K2i`B+b T bb2/ b Q#HB; iBQMb 7  
 #miBQM- Bi Bb HbQ /2bB` #H2 iQ ? p2 +2`i BM /Bp2`bBiv B  
 Q#HB; iBQMbX h?Bb K2 Mbi? ii?2 /Bbi`B#miBQMb Q7 i?2b2 Q  
 r? i bT`2 / Qmi- 7QHHQrBM; bQK2i?BM; i? i HQQFb HBF2 MQ  
 AM Q`/2` iQ i2bii?2 /Bp2`bBiv bT2+i- i?2 H; Q`Bi?K Bb`mM  
 MQ/2b T bb2/ iQ Bi b M Q#HB; iBQMX AMbi2 / Q7 Dmbi +?QQ  
 iBK2- i?2 H; Q`Bi?K b?QmH/ 2Mbm`2 i? i 2 +? Q7 i?2 Qi?2` K2i`  
 BMTmi + M HbQ #2 b2BMbM2 #2H2mHib `2 b?QBM } ;m`2

h #H2 eX#; Q`Bi?K BMTmi bT2+B7vBM; i?2 bBx2 Q7 i?2 ;2M2  
 aBx2 Q7 +QHHR2yiBQM,  
 P#HB; iBQMb,

J2i`B+	J2 M p Hm2QMqiQMB+
LmK#2` Q7 MQ/2	b8y u2b

h?2 /Bp2`bBiv ? b #22M 2p Hm i2/ 7Q`eiX2URVQrBeXkBMV; m`2  
 6Q` MmK#2` Q7 MQ/2iBBM Q/2Hb 7QHHQr SQBbbQM /Bbi`B#m  
 q?2M HQQFBM; i i?2 K2i`B+bTbb2 HbQ b22K  
 iQ 7QHHQr mMBKQ/ H M/ SQBbbQM@HBF2 /Bbi`B#miBQMX  
 BM }; neX2kUB2VbQK2r? i /Bz2`2Mi BM i? i Bi 7QHHQrb /Bbi`B#  
 p`B M+2 i? M i?2 Qi?2` K2i`B+bX "v 2t KBMBM; i?2 M HvbBb  
 BMj - Bi #2+QK2b +H2 ` i? i i?Bb K2i`B+ i2M/b iQ 7QHHQr /B  
 p`B M+2 +QKT `2/ iQ i?2 K2 MX h?Bb K2 Mbi? ii?2 M ``Qr /E  
 eXkU2M #2 +QMbB/2`2/ b iBb7 +iQ`vX aBM+2 i?2 /Bbi`B#miBQ  
 eXk22K`2 bQM #Hv /Bp2`b2- Bi + M #2 +QM+Hm/2/ i? ii?2 /Bp  
 T bb2/ b Q#HB; iBQMb Bb BMbm`2/X

# fYk `nNNCN< iCL3

AM b2+9XQM2 H; Q`Bi?K r b ` ;m2/ iQ ? p2 `mMMBM; iBK2 K  
 QM i?2 bBx2 Q7 i?2 T`Q/m+2/ KQ/2H- b r2HH b i?2 iBK2 7Q`  
 T bb2/ b Q#HB; iBQMbX AM i?Bb b2+iBQM- i?Bb ?vTQi?2bBb B  
 `mMMBM; iBK2 rBHH HbQ #2 2p Hm i2/ 7Q` 72 bB#BHBiv 7Q` m  
 QM +QKTmi2` rBi? i?2 bT2+B7vBM; i?2 bBx2 Q7 i?2 ;2M2  
 aBx2 Q7 +QHHR2yiBQM,  
 P#HB; iBQMb,

h #H2 eX#2+B}+ iBQMb Q7 i?2 +QKTmi2` mb2/ iQ `mM i?

JQ/2H	G2MQpQ h?BMFT / h99yb
S`Q+2bb	AMi2HU_V *Q`2UhJV Bd@9eyyl *SI! kXRy :>x kXe
_ J	Rk :"

U VmK#2` Q7 MQ/2b

U#Vmk#2` Q7 +iBpBiB2b

U+Vmk#2` Q7 ; i2r vb

U/VQMi`QH ~Qr +QKTH2tBiv

U2VQ2{+B2Mi Q7 +QMM2+iBpBiv

6B;m`2 eXk,i`B#miBQM Q7 K2i`B+b MQi BM+Hm/2/ BmX82 BMTmi

fYkYS bCy3 R8 ;3N3a j30 KR03lc

++Q`/BM;iQi?2?vTQi?2bBb-i?2 H;Q`Bi?K b?QmH/i F2 HQM;2`  
KQ/2HbX hQi2bii?Bb-i?2 H;Q`Bi?K Bb`mMi?`22 iBK2b @ QM+2  
KQ/2Hb Q7 Ry MQ/2b- QM210Q MjQ/2Bx2M/ MQi?2`7Q`Ryy MQ/2b  
i2bi b2imT M/`2bmHib + Me#2ab?2B+P BMQR#H2 ii?2`2 Bb BM/22/  
/Bz2`2M+2 #2ir22M i?2`mMMBM;iBK2bX h?Bb bmTTQ`ibi?2?vT  
iBK2 Q7 i?2 H;Q`Bi?K Bb ;`2 iHv /2T2M/2Mi QM i?2 bBx2 Q7 i?2  
BM 7 +i`mMb KQ`2 i? MT`QTQ`iBQM HiQ i?2 bBx2 Q7 i?2 T`Q+2

#2 b?QrM i? i TQHvMQKB H`2;`2bbBQM HBM2 Q7 i?2 b2+QM  
 }ii2/ iQ i?2 `mMMBM; iBK2- b eXQhMBBMB; rBM2 HBM2 rBi? i?2  
 T2`7Q`K2/ BM9K2+1BQ1Mbi i2b i? ii?2 `mMMBM; iBK2-BbXT`XQTQ`  
 MQi HBM2 `X

h #H2 eX0pi`2bmHib 7Q` /Bz2`2Mi bBx2b Q7 i?2 ;2M2` i2  
 :2M2` i2/ KQ/2Hb, Ryy

LmK#2` Q7 MQ/2b	hBK2 2H Tb2/ T2` KQ/2H
Ry	yXy38 b
jk	yX9je b
Ryy	jX8dy b

6B;m`2 eXT,QHvMQKB H`2;`2bbBQM HBM2 Q7 /2;`22 k }ii2/ iQ  
 i?2 H;Q`Bi?K BM i2`Kb Q7 i?2 MmK#2` Q7 MQ/2b ;2M2`

fYkYI +RLUnj jCRN iCL3 R8 K3jaC,c

++Q`/BM; iQ i?2 M Hv0B0Q27`m2M+MBQM iBK2 Q7 i?2 H;Q`Bi?K  
 #2 /2T2M/2Mi QM i?2 +QKTmi iBQM iBK2 Q7 i?2 K2i`B+b mb2/X  
 Q7 /Bz2`2Mi +QKTmi iBQM H +QKTH2tBiv ? p2 #22M +?Qb2M>  
 K2i`B+ Bb p2`v bBKTH2 iQ +QKTmi2- M/i F2b QMHv +QMbi Mi i  
 h?2 MmK#2` Q7 +v+H2b K2i`B+ Bb ?Qr2p2` #Bi KQ`2 +QKTH2  
 O(s<sup>2</sup> logs) iBK2 BM i?2 BKTH2K2Mi BiB Q72-brB22 Q7 i?2 ;2M2` i2/ T  
 KQ/2HbX A7 i?2 M HvbBb Bb +Q``2+i- Bi b?QmH/ i F2 bm#b  
 H;Q`Bi?K rBi? i?2 MmK#2` Q7 +v+H2b i? M rBi? i?2 MmK#2`  
 iQ K F2 i?2 bBx2 Q7 i?2 T`Q+2bb KQ/2Hb B``2H2p Mi- #Qi?`m  
 KQ/2Hb Q7 bBx2 jy #v HbQ T bbBM; i?2 MmK#2` Q7 MQ/2b b

h?2`2bmHib Q7 i?2 i2K2B2M`iH#H2?Qr bB;MB}+ Mi /Bz2`2M+2`mMMBM; iBK2b r?2M mbBM; i?2 irQ K2i`B+b- rBi? i?2 bBKTH2b h?2 M HvbBb Bb i?2`27Q`2 +Q`2+i BM bbmKBM; i? i i?2 K2i`B+`2 BKTQ`i Mi 7Q` Bib`mMMBM; iBK2X

h #H2 eX2pi`2bmHib 7Q` r?2M mbBM; K2i`B+b rBi? ?B;? M/ HQR

:2M2` i2/ KQ/2Hb, Ryy

J2i`B+b	hBK2 2H Tb2/ T2` KQ/2H
LmK#2` Q7 MQ/2b,	jy 89d b
LmK#2` Q7 +iBpB	iB2b, ky
LmK#2` Q7 MQ/2b,	jy 8 NRN b
LmK#2` Q7 +v+H2	b, 8

fYkYk 73 cC\$CICjw

AM Q`/2` iQ i2bir?2i?2` i?2 ;2M2` iBQM H;Q`Bi?K Bb 72 bB#H2 7 iBK2 rBb2- i?2`mMMBM; iBK2 Q7 i?2 H;Q`Bi?K Bb K2 bm`2/ r?2M /Bz2`2Mi K2i`B+bX AM Q`/2` iQ #2 72 bB#H2 7Q` mb2 BM T` +iB #H2 iQ +QMbi`m+i`2 bQM #H2 bBx2/ +QHH2+iBQM BM M KQ /Bb`mTii?2 rQ`F Q7 i?2`2b2`+?2`b mbBM; BiX 6Q` i?2 Tm`TQb2 iQ ;2M2` i2 T`Q+2bb KQ/2H +QHH2+iBQM bBx2 Q7 kyyy KQ/2Hb #2 +QMbB/2`2/ b iBb7 +iQ`v 7Q` i?2 72 bB#BHBivX h?2 MmK#2` k i?Bb Bb i?2 +QK#BM2/ bBx2 Q7 i?2 M Hvx2/jj) H?BHB B2 T?Q+2bb FBM/ Q7 T`Q+2bb KQ/2H b2ib i? i i?2 ;2M2` iBQM H;Q`Bi?K Bb + #2M+?K`FbX

h?2 i2bib2imT M/`2bmHib + M X2hb?22i2 iBIB b #rH2 7Q` Ryy KQ/2 M/ i?2 iBK2 iQ ;2M2` i2 kyyy KQ/2Hb Bb 2ti` TQH i2/ 7`QK i?Bb i?2 MmK#2` Q7 KQ/2Hb- MQi i?2 bBx2 Q7 i?2 KQ/2Hb- bQ Bi Bb TQ h?Bb K2 Mb i? i i?2 H;Q`Bi?K Bb K2 Bb i?2 5320 b2+QM/b- Q` 3N KBMmi2b- iQ ;2M2` i2 kyyy KQ/2HbX A7 H27i iQ`mM Qp2`MB;?i HmM+?iBK2- i?Bb b?QmH/ MQi bB;MB}+ MiHv BKT2/BK2Mi`2b2`

Ai Bb ?Qr2p2` BKTQ`i MiiQ MQi2 i? i i?2 KQ/2Hb T`Q/m+2/ BM i KQ/2bi bBx2- M/ BMTmi T`Q/m+BM; H` ;2` KQ/2Hb rQmH/ HBF2Hv`mMMBM; iBK2- b /2KQMbiè XpX KBM`b2QHBQBM; 7`QK i?2 }M/BM; b i? ib2+iBQM- M/ bbmKBM; b[m`2//2T2M/2M+2 QMi?2 bBx2- B kyyy KQ/2Hb Q7 bBx2 Ryy rQmH/ i F2 #Qmi MBM2 ?Qm`b- r?BH2 rBi? Ryyy MQ/2b 2 +? rQmH/ i F2 #Qmi Rdy ?Qm`b- Q` d / vbX r?BH2 i?2 H;Q`Bi?K Bb iBK2 @rBb2 }i 7Q` mb2 BM T` +iB+2 7Q` i Bb TQbbB#H2 i? i i?2`mMMBM; iBK2 Q7 i?2 H;Q`Bi?K 2t+22/b r 72 bB#H2 r?2M /2bB`2/ bBx2 Q7 i?2 KQ/2Hb #2+QK2b iQQ H` ;2X i? i i?2 bBx2 Q7 i?2 KQ/2Hb rBHH ? p2 iQ 2t+22/ Ryy KQ/2Hb- M Q`/2` Q7 i?Qmb M/ KQ/2Hb 7Q` i?Bb iQ #2 i?2 + b2X

y- 4Y vi\_ = p Gs~ Ys Hbq zPC - YlbqzP \ .. SzP scfCq Y@s GqC^z z%Cs bH \ Czfsi

K C^ Cq zC@ \ b@C%	cCE
[ Czfs	] ~\ 4Cq bH^ b@Cs= JCE ; b^zqbY•b... <b\ eY C: S% cCE ; b^ ^Cz bq PCz CplC^ C% Cui
y S\ C CY esC@ eCq \ b@CY	ivv s

, s \ C^zS^@S^ sCzSb^ IiCru> Sz S Pb..CfCq eqp4- 4Y%ebssSAYC zb qC@-CzPC q-^Q  
 ^S^L zS C bHzPC - YlbqzP \ sL^S < ^zY%4% S eY C^zS^L - < -PS^L \ C-P- ^S\ Hbq  
 < Y~YzS^L zPC \ Czfs> s~<P zP-z G <P \ Czfs ..SY^b^Y%4C < Y~YzC@ I zS Gs Hbq  
 G <P ^C..e-zCq^ zP-z S <PbsC^><b\ e- qC@zb zPC cuCEzS Gs Sz S <-qf^zY%e- Y~YzC@  
 .. PSC zPS: sPb~Y@ qC@-CzPC zS C sL^S < ^zY%Hbq - Y\ b@C% Sz szSY..b^ z <P- ^LC  
 zPC zS C <b\ eY C: S% bHzPC - YlbqzP \ > s~<P zP-z LC^Cq zS^L fCq%Y qLC \ b@C% \ SLPz  
 szSY4C ~^Hf sSAYC S^ \ - ^%sS~ zS^si

### 6.4 Support for Metrics

rCzSb^ vici{i{ @S<~ssCs sPbqz<b\ S^L bHzPC - YlbqzP \ S^ s-eebqzS^L \ Czfs zP-z - qC  
 ^bz @C^ @C@ Hbq <Cqz- S^ f- YGsi yPCqC - qC Pb..CfCq - Yb bzPCq sPbqz<b\ S^Ls S^ zPC  
 - YlbqzP \ ..PC^ Sz <b\ Gs zb s-eebqzS^L \ Czfs> zP-z - qC^bz - s G sY%o- ^<bfcCq@ 4%  
 zCzsi ; b\ e- qC@zb zPC \ Czfs S^C^zS^ C@S^ q{:>zPCqC - qCb^Y%o s-4sCz bHzPbsCzP-z  
 - qC...CYs~eebqC@ 4%zPC - YlbqzP \ i

r b\ C \ Czfs zP-z < ^ ^bz 4C s-eebqC@ 4%zPC - YlbqzP \ S^ Ss <-qf^z Hbq >  
 - qC S eC@C@ 4%zPC LC^Cq zS^ Hq \ C.bqW- ^@ C^eqssSf^C^ss bHzPC ; G; ~sC@ 4%  
 dXKi rS^CzPS b^Y%eqp@<Cs sqz<z-qC@ \ b@C%> - ^@ ^CfCq <b^z- S^s @CSL^ Cqpfq  
 s~<P - s zPCeqsC^<CbHfC @Y<W>- ^@C^s-qS Yf^C^ss S^ zPCeq<C>ss>scfCq Y\ Czfs  
 S^C^zS^ C@S^ q{: @b ^bz \ - W sC^sC zb s-eebqz sS^<CzPC%o..b~Y@ ~s~ Y%ob^Y%CfCq  
 z Wb^ - sS^LYC f- Y-G a^CC^ - eYCs zPC <b^ ^Cz bq \ S\ - z-zP>..PSP..b~Y@ b^Y%CfCq  
 z W- f- Y-C bHfC sS^<CzPC; GK @bG ^bz - Yb...Hbq \ S\ - z-PC@L- zC.: %si , ^bzPCq  
 C^ - eYCs zPC sqz<z-qC@^C>..PSP..b~Y@ - Y.: %4C c>sS^<CzPC q- Ys bHdXK b^Y%o  
 - Yb...Hbq sqz<z-qC@<b\ eb^C^zs>..PSP - qC@Cs<f^C@S^ q{: ..PC^ @C^ ^S^L zPC \ Czfsi

R^ bq@Cq zb - Yb...Hbq s-eebqz bHs~<P \ Czfs> zPC; GK \ ~sz - Yb...Hbq S^<bqCz  
 eqp<C> \ b@C%>..PSP S zb s-%a b@C% zP-z <b^z- S^ @CSL^ Cqpfqi a^C...%bH@bS^L  
 zPS: Sz zb S^zpb@<C<P- ^LCS @fz-zY%S^ zb zPC; GK i, ^bzPCq sbY-zS^ ..b~Y@ 4Czb \ - W  
 zPS- Hf z-qC bH ebssSAYC \ S q zS^ zb - @S GqC^z Hq \ C.bqWbH-S^L eqp@<zb^ q- Ys  
 S^ szC @bHzPC; GK >- s sWz~PC@b-z S^ sCzSb^ vici{iJi 3%S^zpb@<S^L - ^ d ~sf- YC^z  
 bHzPC <b^ sqz<zb^ q- Ys ~sC@S^ qC> zPC sb- ^@^C^ss eqpeCq%o s @C^ @C@S^ qD ..b~Y@  
 ^b Y^LCq 4CL-- q ^zC@ yPS \ G^s zP-z zPC \ b@CY< ^ ^b...<b^z- S^ @C @Y<W>- ^@  
 s-eebqz zPC LC^Cq zS^ bH4-sS^C^ss eqp<C> \ b@C% zP-z - qC zq^sifCq 4Y Hf \ - ^%o  
 - q4Sq q% d Czfs^ Czi

, ^bzPCq sPbqz<b\ S^L S^ zCq\ s bHs-eebqzS^L \ Czfs S zPC Y<WbHs-eebqz S^

zPCS\ eY\ C^z-zb^ HbqP- ^@S^L @S Gq^z @Szqf4-zb^s Hbq\ CzqfSi ? S Gq^z\ CzqfS  
 bhC^ - eeG q.. SzP @S Gq^z @Szqf4-zb^s S^ @S Gq^z qC YqfC eqp<Csz \ b@CysCzs>..PSP  
 S Cfs@C^z Hb\ zPCqC YqfC bYc-zb^s- ^- Y%@S^ q{ :i a ^Cqf- \ eYCs zPC-bC <C^z  
 bh<b^ ^C<zsfS%...PSP S sPb..^ zb HbYb...- sL^S <- ^zY%@S Gq^z @Szqf4-zb^ zP- ^  
 bzPCq \ CzqfS S^ sC-zb^ vi|i yPS \ G ^s zP-z S^ bq@Cq zb LC^Cq zC \ bqC qC Ysz<  
 eqp<Csz \ b@CysCzs> Sz ..b~Y@ 4C 4C^C^ <S YHbq zPC- YbqfzP\ zb 4C- 4Y zb s~eebqz -  
 ...S@Cq q ^LC bh@Szqf4-zb^si

Rz S - Yb ^bz ebssS4Y Hbq zPC- YbqfzP\ zb s~eebqz \ b^bz^S<- Y%@C<qC s^L \ CzQ  
 qfS - z Ss <- qf^z sz-zG yPS S @-Czb - ^ S eY\ C^z-zb^ Ss-C...PCqC zPC- YbqfzP\  
 S^ bz zbY@ zb szbe SHzPC \ Czqf: HYs 4Cb...zPC z qLz f-YC- ^@ S qY zsfC%G sS%  
 " †- 4Y R - Yb P-s eqp4Y\ s s~eebqz^L \ CzqfS zP-z - qC \ b^bz^S<- Y%@C<qC s^L>  
 4-z ^bz b^Y%z VC b^ f-YGs m N>..PSP S - Yb @-Czb - ^ S eY\ C^z-zb^ Ss-G R^  
 bq@Cq zb 4C- 4Y zb eqp@sz zPC^~\ 4Cq bh4q ^<PGs S^ - L zC..%e- zzCq^>zPC^~\ 4Cq  
 bh4q ^<PGs P-s 4CC^ sCz zb | CfCq%zS G>..PSP Y Ss zPC q ^LC bhf^ YGs \ CzqfS  
 4- sC@b^ zPC @LqC bh^b@Cs <- ^ z Vq

# CHAPTER 7

## Conclusion

yPS ..bqWeqpebsGs - LC^Gq zB^ - YbqfP\ zP-z eqfS@Cs @SfCz <b^zpbYbHzPC<P- q <Q zCfszSs bHLC^Gq zC@ 4-sS^Gss eq<Gss \ b@C@>..PCq zPC<P- q <CqfszSs - qCseG-S^C@ -s \ Czqfs - Y^L ..SP zPCq @CsSfC@ @Szqf4-zB^si B- <P eq<Gss \ b@CYs LC^Gq zC@ ..SP qCseCz zb - z qCz f- Y-C Hq G <P \ Czqfs> ..PS-P - qC eq@-<C@ Hq\ zPS @SzqfC 4-zB^i yPC- YbqfP\ <b^zS^~b-s%<- Y-YzGs zPC eq4- 4S%bHkPbbsS^L - \ b^L - sCz bH4- sS^ eq@-<ZB^ e- zCq^s>4- sC@b^ zPC 4C^C^ z bHkPbbsS^L G <P e- zCq^ ..SP qL- q@s zb eq@-<S^L - \ b@CY..SP zPCseG-S^C@ \ Czqfsi ,, P- ze- zCq^s- qC4C^C^ <S Y bq ^bz S 4- sC@b^ Pb.. \ ~<P <YsGq zb zPC z qCz f- Y-Gs G <P e- zCq^ ..b-Y^Lz zPC \ b@C@ - ^@ Pb...zPC e- zCq^ <b^zqf4-zGs zb zPC LC^Gq zB^ zCq\ S^ - zS^L - z zPC qLPz zS G

yPCeq@-<C@ eq<Gss \ b@CY<bY<zb^s- qCLC^Gq Y%> - <bq@ ^<C..SP zPCseG-Q S^C@ <P- q <CqfszSsi yPC qfs- Ys f- q%4Cz .CC^ \ Czqfs> - ^@ ..Gq b^ - fCq LC ..SPS^ vQCEh bHzPC @CsSfC@ \ G^ Hq @S Gq^z \ Czqfs> - ^@ P- @ - Lbb@ - YL^ \ C^z ..SP zPC qCqC^ <C @Szqf4-zB^i yPC \ b@C@ - Yb sPb... - @Szqf4-zB^ qGs 4S^L - ^bq\ - Y @Szqf4-zB^ Hq <P- q <CqfszSs zP- z @b ^bz P- fC- seG-S^C@ @CsSfC@ @Szqf4-zB^> - ^@ sPb..s - ^ - fCq LCq-^^S^L zS CS @S- zS^L Hq sS^S% Hq eq <ZS- Y-sC..PC^ LC^Gq zS^L \ b@C@ bH q-^@ cCE^b@Csi

„ PSCzPC- YbqfP\ @bGs - <PSCfC Lbb@ qfs- Ys>zPCqC - qC szSYsb\ CsGfb-s Ys S- Q zB^s zP- z \ - W@s S eq <ZS- YS^ Ss <-qq^z sz- zG , sS^S^ < ^z @q ..4 <W@s Ss Ys S^C@ s-eebq bH Czqfs> \ - S^%<-C zb zPC 4- sS^ LC^Gq zB^ e- zCq^s ~sC@ yPC- YbqfP\ - Yb @CzGq\ S^Gs ..PC^ zb zCq\ S^ - zCLC^Gq zB^ ^b^ QezS - Y%<- ^@ P- s eq4Y\ s P- ^Q @S^L Y<- Y\ - †S - - ^@ S^zGq@eC^@<C bH Czqfsi Ob..CfCq @GseS^C Ss @q ..4 <W> zPC- YbqfP\ S - ^S^C” qsz szCe zb.. q@s @CfCbeS^L - eq <ZS- Y%< sS^Y\ CzPb@ Hq LC^Gq zB^ bHeq<Gss \ b@C@ 4- sC@b^ seG-S^ < zB^ bHzPC @CsSfC@ <P- q <CqfszSsi

### Future work

; P- ezCq v @S<-ssGs ebss^Y<sbY-zB^s zb zPC- HqC\ C^zB^C@ sPbq<b\ S^Ls>zP- z ..SY S eqfjCb^ zPCeGqHq - ^<CbHzPC- YbqfP\ i yPGsCbY-zB^s zb zPC \ bsz sS^S^ < ^z @q ..4 <W< ^ 4Cs- \ \ - qS^C@ -s S^zpb@-S^L zPC HqYb..S^L zb zPC- YbqfP\ >-s ..CY -s” †S^L zPCS s eY\ C^z-zB^ Ss-Gs S^C^zS^C@ S^ <P- ezCq Ii

á , ^C...sCz bH4- sS^ LC^Gq zB^ e- zCq^s zP- z @b ^bz <b^z- S^ eY<CPbY@Cq <b\ ebQ ^C^zs>s<P zP- z zPC \ b@CYs^ ^b^Q\ 4S^~b-s%<C^ ^C@- z- YebS^zs bHLC^Gq zB^i

d-zzCq^s sPb~Y@- Yb 4C-s-zb\ S- s ebssSAYC>sb zPC%<- ^ ^bz 4C @G-b\ ebsC@  
S^zb bzPCq e-zzCq^si

á , s\ - qCq \ CzPb@ Hq @CzCq\ S^S^L zPC 4C^C z bH<Pbbs^L G <P e-zzCq^> 4%  
YbW^L HzPCq-PC @S^ zPCLC^Cq zS^i

á , LY4-Y^bzS^ bHzPC 4C^C z bHzCq\ S-z^L>..PGC zPC LC^Cq zS^ @bGs ^bz  
zCq\ S-zC4HqC- ^ bezS - YsbY-zS^ P-s 4CC^ H-^@

G-z-q...bqWb^ zPCeqpebsC@- YbqzP\ sPb~Y@H<-s b^ q@CSL^S^L zPC- YbqzP\  
zb S^<bqzC zC zPC- 4bfCsbY-zS^si XSW..S<S~4sC ~C^z..bqWb^ sS SYq- YbqzP\ s  
sPb~Y@ z VC ^bzC bHzPC C^eCqC^<Cs \ -@C S^ zPS ..bqW S^ sC q-P Hq - eq <zS- Y%  
H sSAYC \ CzPb@ Hq LC^Cq zS^L eq<Css \ b@C6 ..SP - PSLP <b^zqYbHzPC b-ze-z  
<P-q <CqzSsi G-qzPCq\ bq>zPC 4-sS S@G s bHzPCeqpebsC@- YbqzP\ <b~Y@- Yb 4C  
-eeY@S " C@s b-zsC bH~sS^C s eq<Css \ b@C^L>s~<P -s Lq eP s%zPCSS>- " C@  
..PS-P sCC C@zb Y<W- sS SYqsbY-zS^ 4-sC@b^ Lq @~- YbezS S-zS^ Hq LC^Cq zS^L  
Lq ePs ..SP <Cq- S^ <P-q <CqzSsi



# APPENDIX A

## Project Planning

„ PC^ ..bqW^L b^ - eqbLz>P- fS^L - eY^ Hbq zPC eqbLqss zb..: q@s cG <PS^L zPC C^@ Lb Ys-<<GssHYW%\$ fCq%\$ ebqz ^zi 3%PbbsS^L ^bz zb ..bqW HZqsb\ CVW @bHeY^> Sz S - q~ - 4Y zP- z b^CS <b^s<S~sY%eY^^S^L zb HSY

y PC eqbLz ..bqWb^ zPS zPGSS P-s 4CC^ szq-<z-q@ S^z zb .bQ.CCWseqs^z> - <b^<Cez zP- z P-s 4CC^ 4bqpb..C@ Hb\ zPC r<q\ Hq\ C..bqW d- qz~Y q%dbq zPS eqbLz> Sz P-s \ G ^z zP- z- z zPC 4CLs^S^L bHCfCq%seqs^z> - sCz bHLb Y Hbq zPC seqs^z P-s 4CC^ sCzi rS^<C sb\ C bHzPC -<SfSSs bHzPC eqbLz ..bqW- qC ^bz -s z ^LSAYC-s @CSfCq^L sb\ CH^<Sb^ - YS%\$ - <b\ e-zCq eqbLq \ > Sz P-s 4CC^ zPC SeC zb \ - W zPC qS~Ys bHzPC Lb Y bHC <P seqs^z -s z ^LSAYC-s ebssSYi

3CHbq zPC 4CLs^S^L bHC <P seqs^z> - ^ S Hbq - Yseqs^z eY^^S^L ...: s - Yb - Y..: % eGqHbq @i ? ~q^L zPS -<SfS%zPC eqbLz eY^ -s @C ^C@ 4CHbq zPC 4CLs^S^L bHzPC eqfSb-s seqs^z <b-Y@ 4C qfS@> zb -<<b\ \ b@ zC - ^%G-Gss- q%P- ^LGS - ^@ zb - Yb... 4SLCq z-sW\ bq \ bqC - 4szq <z Lb Ys zb 4C 4qW^ @b..^ S^z sb \ - Yq\ bqC seCS <z-sW - ^@ Lb Yi pSLPz 4CHbq zPC seqs^z eY^^S^L> - \ C^S^L 4Cz..CC^ zPC sz-@C^z - ^@ zPC - @fS^Cq...: s s-PC@-Y@ yPS sCqfC@-s - sz-z-s \ C^S^L zb WCe zPC - @fS^Cq ~e zb @ zC - ^@ - Yb..C@ Hbq - @S<-ssb^ bH..P-z zPC ^C^z szces bHzPC eqbLz sPb-Y@ 4C sb zPS <b-Y@ 4C S^<Y@C@ S^ zPC qfS@> eY^i yPGC \ C^S^Ls ..Cq zPC \ - S^ <b^z <z 4Cz..CC^ zPC - @fS^Cq - ^@ sz-@C^z zPq-LPb-z zPC..bqW eCq@i

### Working on the Thesis

yPC eqbLz ..bqW..: s \ - S^Y%@SfS@C@ S^z b - eqCS S^ - q%qSG qP eP- sC- ^ - YbqfP\ @CS^ - ^@ S eY C^z zS^ eP- sC- ^@ - ..qfS^L eP- sG yPC eqCS S^ - q%qSG qP se- ^^C@ zPC z..b” qz seqs^z> - ^@ zPC S^z zS^ ..: s zP- z- HZq zPC eP- sC- s’ <S^> SH^bz <b\ eYzC b fCqfSC... bHzPC qSG qP” C@ sPb-Y@ P- fC 4CC^ b4z S^C@s~P zP- z zPC..bqW bH@CS^S^L zPC- YbqfP\ <b-Y@ 4CLs^i

y PC- YbqfP\ @CS^ - ^@ S eY C^z zS^ eP- sC <b^sSzC@ bHScfCq Yseqs^z zP- z G <P sPb-Y@ @CSfCq b^ zPC Lb Ys sCz Hbq G <P seqs^zi „ PSC \ - ^%eqbLz> zP- fC - sb\ C.P- z sCz SeC bH.P- z H^<Sb^ - YSs sPb-Y@ 4CS^ zPC s%sz\ > zPC \ - S^ <P- YC^LC bHzPS s%sz\ ...: s ^bz zb S eY C^z ..P-z ..C... ^zC@ Sz zb @b> 4-z q zPCq zb @CS^ Ph... Sz sPb-Y@ @b Si yPCqHbq> S^ <b^zq sz zb - zq @Sb^ - Ys%sz\ > G <P seqs^z ...: s bqc^zC@ zb..: q@s 4bzP @CS^S^L> S eY C^z S^L - ^@ Cf- Y- zS^L - seCS <- YbqfP\ > ..PS zPCs- 4sd ~C^z seqs^z..b-Y@ S eqfCb^i yPCSeC bHzPS - eeqP <P bHzCq zSfC% @CS^S^L - ^@ PbeCHY%\$ eqfS^L b^ zPC - YbqfP\ ...: s zb q@<C zPC qSWbH^b

H^<Zb^S'L - YlbqfP\ 4CS'L <C zC@ - z zPC C^@ bHzPC eP- sG R'szG @- sS eY 4-z ..bqM^L - YlbqfP\ ...s S eY C^zC@ @-C^L zPC " qsz <b-eY bHseqf^zs> - ^@ ...s zPC^ S Cq zsfC% S ecfC@ @-C^L s-4sC ~C^z seqf^zs> 4-z -Y.:% ..bqM^Li

„ PSC..bqM^L b^ zPceqlCz zPC@CSL^ - ^@S eY C^z zS^ eP- sC<P- ^LC@ 4bzP S^ zCq\ s bHzPC zS C- YbzzC@- ^@ zPC Lb- Y> bq \ SCszb^Cs> sCz Hbq Si „ PSC S^ zPC 4CL^S'L> -s sCC^ Hb\ zPC S^S YeY^ S " L-qC, ic> z.b \ SCszb^Cs ..Cq sCz Hbq zPC- YlbqfP\ >..PCq \ bsz bHzPC @S Cq^z \ Czqs sPb- Y@ 4C s-eebqC@- Hq seqf^z v>- ^@ zP- z zPC<- e- 4S^S sPb- Y@ 4C C^e- ^@C@ ~^zS zPC C^@ bHseqf^z cE..PC^ zPC ..PbY S eY C^z zS^ sPb- Y@ 4C @b^G , s <- ^ 4C sCC^ Hb\ zPC " ^- YeY^ S " L-qC , i|> zPs Y% z <P- ^LC@ l~S- 4Si GSz bH Y zPC z.b - Hbq C^z b^C@ \ SCszb^Cs ..Cq C\ bfC@ HSq% G q% ^@ qeY<C@ 4%I S Cq zS^ s bHzPC- YlbqfP\ >..PCq zPC " H^P - ^@ " ^- YS Cq zS^ ...s eY ^C@ z " ^SP - Hq seqf^z D^S szG @ bHzC^i yPs - Yb \ -C zPC eP- sCs bHzPC- YlbqfP\ @CSL^ - ^@S eY C^z zS^ \ bq @S z< z Hb\ zPC ..qS^L eP- sC C^C^ zPb- LP> -s <- ^ 4C sCC^ Hb\ zPC " ^- YeY^> zPCq ...s szSYsb\ C bfCq e S^ <Cz- S^ ..qS^L - <Sf^S Csi

, z zPC 4CL^S'L bHzPC @CSL^ - ^@ S eY C^z zS^ eP- sC zPC \ -S^ S@G ...s - <Z- Y% Yq @%fC% S S^ q z zPC b^C S^ zPC " ^- Y- YlbqfP\ > ^- \ C% z b S Cq zsfC% \ bfCz b... q@- sCz bHz- qCz f- YCs Hbq G<P \ Czq: 4%q<- Y- Yz^L zPC..CLPz s Hbq G<P ^C..LC^Cq zC@ e- zCq^i yPC ...% bH@b^S L zPs ...s Pb..CfCq S^S Y% 4S @S Cq^z Hb\ zPC- eeq<P z- V^ S^ zPC C^@ R'szG @ bH- Y- Yz^L - eC@C^ @z- qCz f- YC HbYb..S'L - sCC^ S^L% G Ysz- dbSsb^ @Szq^ zS^> zPC S@G ...s zP- z zPC- YlbqfP\ ..b- Y@- ~zb\ - zS- Y% zCq\ S^ zCLC^ Cq zS^ sb zP- z zPCLC^ Cq zC@ \ b@C^ ..b- Y@ HbYb... s~<P- @Szq^ zS^ i yPs S@G Pb..CfCq z-q^C@ b-z z b 4C z b @S <- Y- ^@<b\ eY C^> sb - Hq seqf^z v>- @S Cq^z - eeq<P P- @ z b 4C z- V^> Y@ S^L z b zPC \ -S^ S@G bHzPC " ^- Y- YlbqfP\ 4CS'L - @bezC@ a zPCq .S C zPC eqlCz ..bqWfCq% .CY HbYb..C@ zPC Lq @- YS ecfC C^z bHzPC- YlbqfP\ Hbq G<P <b\ eY zC@ seqf^z i

„ PC^ zPC S eY C^z zS^ bHzPC- YlbqfP\ ...s " ^SPC@ zPC 4- YWbHzPC zPGsS ..qS^L ...s ~^@Cz- V^> e- q YCY z b4z- S^S'L zPC " ^- YqCs- Ysi , s <- ^ 4C sCC^ Hb\ zPC " ^- YeY^> sCfCq YLb- Y ..Cq^ bz \ Cz S^ zPC seqf^zs> 4-z ..Cq szSY " ^SPC@ zP- ^V^ z b sb\ C 4- Cq zS C S^ zPC " ^- Yseqf^z - ^@- z zPC<bsz bH ; Pqsz\ -s f- < zS^ i „ PSC zPCq ..Cq \ - % @S Cq^ <S 4Cz .CC^ zPC S^S Y- ^@ " ^- YeqfCz eY^> zPs ...s zPC S^ zC^ zS^ Hb\ zPC 4CL^S'L i , s \ bq C S^ Hbq\ - zS^ - 4b-z ..P- z ..b- Y@ 4C zPC 4Gsz ...% z b eq<Gss <- \ C z b YLP zPC eqlCz eY^ ..b- Y@ <P- ^LC z b - <<b\ \ b@ zC zPs ^C...S Hbq\ - zS^> 4% eY ^S'L - z zPC Ysz qS e b^ s S^ YC \ b\ C^z i

	Sprint number	Goals	Sprint description
Aug	1 preliminary research		Preliminary research in process properties and generation & dataset inspection
	2 preliminary research	<b>Preliminary research &amp; project plan</b>	Analysis of preliminary properties in process models & project plan
Sep	3 Algorithm design and implementation		Analysis of process models & size parameter generation
	4 Algorithm design and implementation		Generation with CFC parameter
Oct	5 Algorithm design and implementation		Generation with size parameter
	6 Algorithm design and implementation	<b>Support for all generation parameters (metrics) &amp; definition of these</b>	Generation with all parameters
Nov	7 Algorithm design and implementation & Writing	<b>thesis structure proposal</b>	Improve design & write
	8 Algorithm design and implementation & Writing		Improve design & write
Nov/Dec	9 Algorithm design and implementation & Writing		Improve design & write
Dec	10 Algorithm design and implementation & Writing	<b>Full implementation</b>	Improve design & write
Dec	11 Writing	<b>Thesis hand-in deadline</b>	Thesis writing

GSL~qC, ic= yPC'S'S YeqUCz eY^i B- <P seq^z P- s <Cz- S^ Lb- Y>..PSP @G<f4C ..P- z zPC \ - S^ e~qbsC bHzPC seq^z S\$ zb - <PSCfC bq eq@-<C> - ^@ - seq^z @G<qezb^>..PSP Yszs zPC s\ - YCq z- sW zP- z - qC e- q bHzPC seq^z> - zz- <PC@ zb Si yPC @G<qezb^ S U-sz \ G ^z Hbq zPC sz~@C^z ..bqW L b^ zPceqUCz zb qC @- ^@\ - S^z- S^i , Yb>^bzSCzPCH..Lb- Y> ..PSP <- ^ 4C sCC^ - s \ SCzb^G bHzPC eqUCz - z zPS G q%sz LG

	Sprint number	Goals	Sprint description
Aug	1 preliminary research		Preliminary research in process properties and generation & dataset inspection
	2 preliminary research	<b>Preliminary research &amp; project plan</b>	Analysis of preliminary properties in process models & project plan
Sep	3 Algorithm design and implementation		First iteration - algorithm implementation
	4 Algorithm design and implementation	<b>1st algorithm iteration</b>	First iteration - analysis & evaluation
Oct	5 Algorithm design and implementation	<b>2nd algorithm iteration</b>	base weight calculation & 0-generation bias problem & analysis efficiency improvement & algorithm evaluation & <b>metrics section writing</b>
	6 Algorithm design and implementation	<b>3rd algorithm iteration &amp; Metrics section</b>	3rd iteration implementation and evaluation & metrics section writing
Nov	7 Algorithm design and implementation	<b>thesis structure proposal &amp; 4th algorithm iteration</b>	4th iteration implementation & evaluation & Background writing & Thesis structure proposal
	8 Algorithm design and implementation	<b>Final algorithm iteration</b>	Final iteration implementation & evaluation & preliminary introduction section
Nov/Dec	9 Writing	<b>Generation algorithm section &amp; related work</b>	Evaluation & generation algorithm + related work section
Dec	10 Writing	<b>Get final results &amp; write results section &amp; Generation algorithm section &amp; Related work section &amp; Design and implementation section</b>	
Dec	11 Writing	<b>Background section &amp; Design and Implementation section &amp; Related work &amp; Final thesis</b>	Thesis writing

$GSL \sim qC, i | = y PC'' \wedge - YeqfUCz eY \wedge i$

# Bibliography

- 9: „ SY | i di f- ^ @Cq, - Yzi dφ<Css | S'S'L=? S<b/Cq/%; b^Hbq\ - ^<C- ^@B^P- ^<CQ  
 \ C^z bH3~sS^Css dφ<CssCsi cszi reqS^LCq d~4YsPS^L; b\ e- ^%R^<bqpbq zC@  
 |CEi S\$4^={vJ|c\_{JJu>\_uD|vJ|c\_{JJvi
- 9: p~zPr-q, L~SY qQ-f ^i 3~sS^Css eqp<Css \ b@CYS^L=p C/SC... ^@Hq \ C.bqW  
 R^=R^zCq^-zB^- Ytb-q^- YbHdφ@~zB^ B<b^b\ Ssf|CEg Ss^=CE|II|u|i @bS-  
 cCEcCEvvrCE|IQ|u|fCEgCECEQvi
- 9: XC\ - ^, WbLY - ^@; Pqszbs G Yb~zbsi pyK=, qC~qSfC qC YszS- Lq eP LC^Q  
 Cq zbq~sS^L q ^@b\ z%eS^Li R^=XCz-z-q/ bzCs S^; b\ e-zCqr<C^<CfS^<Y@S^L  
 s~4sCqCs XCz-z-q/ bzCs S^, qS^<S YR^zCYLC^<C- ^@XCz-z-q/ bzCs S^ 3SbS^HbqQ  
 \ -zSsg |CEi S\$4^={vJ|CEcu\_Ii @bS-cCEcCEw\_uDQ QvJ|QCEcDCEQD75€8c{i
- 9: K 3BpyOBXa yi yq ^sHbq\ -zB^s- ^@? Cb\ ebsSb^s bH| Czi C^Li R^=XC<Q  
 z-q/ bzCs S^; b\ e-zCqr<C^<C |IJ fc\_Dug> e-LGs {I\_ {uvi Ss^=cvcc{{J\_>  
 CECE\_u|i
- 9: , ^@qC 3~q zS^i dXK|=| ~YSeCpeCzSfC eqp<Css q ^@b\ S-zB^ ..SP b^S^C  
 - ^@b^ S^CSs ~YzB^s i C^Li R^=; C-q,, bqWpbe dφ<C@S^Lscu\_d|f|CEvg-e-LGs c  
 vi Ss^=cvcc{CE|i
- 9: , ^@qC 3~q zS^ - ^@, Yss- ^@preCq@~zS dXK=, Hq \ C.bqWHbqzPCLC^Cq Q  
 zB^ bH4~sS^Css eqp<Css \ b@C^ - ^@zPCsq C^C~zB^ YLs i C^Li R^=XCz-z-q/ bzCs  
 S^ 3~sS^Css R^Hbq\ -zB^ dφ<CssS^L vv f|CEg>e-LGs |cJ |c\_i Ss^=cDvc{Iv>  
 cDvc{JDI @bS-cCEcCEw\_uDQ QvJ|Q|CEccQE|CE
- 9r: [ ~qf %o - \ e4CYE, TbsCeP Ob- ^CTq- ^@GC^LQSS^L Os-i ? Ce 3YCi R^=  
 , qS^<S YR^zCYLC^<C c{J f|CEg>e-LGs Iu D|i
- 9d: TbjLC; -q@bsbi , eeqp<PGs zb; b\ e-zC,, bqWb...; b\ eYcS%o R^=yPCpbYC  
 bH3~sS^Css dφ<CssCs S^ rCq/SC a qC^zC@, qPSGz-qSi , bY\ CCE|\_ci T-Y%o  
 |CE>e-LGs cv |ci S\$4^=cDv|QJCEi @bS- <SzC-YSWQ- qzS-YCQS@c{JCEJci  
 ~qY=Pzze=ww@qbesi @ Lsz~PYi @Cvbe-swfbYYzC^zCw|CEwD|cwi
- 9: TbjLC; -q@bsbi Ob...zb | G s-czPC; b^zpbYb...; b\ eYcS%o bH, C4 dφ<Css  
 - ^@,, bqWb...O- ^@bbW|CE f|CEg>e-LGs c\_\_ |ci
- 9CE d; Pq-sz..sWQ -<PzCYz-Y , zbeQb..^ dCzS^CzQ- sC@-eeep<P Hbq @%Q  
 ^-\ S: ..bqWb... \ b@CS^Li C^Li R^=XCz-z-q/ bzCs S^; b\ e-zCqr<C^<C |vuD  
 f|CEg>e-LGs {{v {I{i Ss^=cvcc{{J\_>CECE\_u|i

- 9c: y Pbl -s Oi ; bq C Cz -Y R'zpb@<zb^ zb , YbqSP^ s>yPSq@B@Sb^i {q@ yPC [ Ry dqSs>|CEi S4^=CEv|CE{DJJ>\_uDCEv|CE{DJD
- 9d: y Pbl -s; ~qf ^>KCP- q@VOCq- ^@, ^@C...X- @a r, d p wf 3~sS^Css 3YCeqS^z } ^@Csz ^@S^L zPC 3~sS^Css dqb<Css pCfC^<C/ b@CY} eeCqr- @@CpSfCq] T> } r, =dqC^zS<CQ- YR^<i>c\_Di S4^=CE{Q|ccJuQi
- 9e: pC <b? SW - ^>| -qCYB X- pbs-> ^@O- Ub , i pCfCqi / - ^-LS^L YqLC <bYcQ zb^s bH4-sS^Css eqb<Css \ b@C^S Q; ~qC^z zC^P^S ~Cs - ^@<P- YC^LCSi |CE|i @bS- cCEcCEvwU <b^eS^@ |CEci c|i CEi
- 9f: pC <b? SW - ^ Cz -Y rS SY qE%bH4-sS^Css eqb<Css \ b@C^S = [ CzqSs - ^@Cf YQ ~-zb^ i R'=R^Hbq\ -zb^ r%szC s {vi| f|CEg>e-LG J\_D I cvi Ss^=CECEJ{u\_i @bS-cCEcCEvwU Ssi |CECEi CEi
- 9g: ? SJWG- PY^@ Cz -Y R'sz- ^z- ^Cb-s rb- ^@Css ; PC<W^L bHR^@-szq Y3~sS^Css dqb<Css [ b@C^S i C^Li R'=f|CEJg @bS-cCEci ci JcD |I{CE
- 9h: B\ @C^ K- ^s^Cq Cz -Y Kq ePfs - ^@? %e- Lq eP rz zS- ^@? %e- \ S Kq eP ? q..S^L ybb^s i R'=R^ Kp, dO ?p, ,, R^ K ra Gy,, , pBi recfLcQ Qy^L> |CE>e-LG c|u cJD
- 9i: , bYQKqP^ - ^@p- YX- ~G ; b\ eYiS%b CzqS Hbq3~sS^Css dqb<Css [ b@C^S i R'=dqb<C@S^Ls bH4PC zP R^zq^ -zb^ -Y; b^HqC^<C b^ 3~sS^Css R^Hbq\ -zb^ r%szC s f3R /CEJg |CE>e-LG c c|i S4^=cQ|JJQeul Qi @bS- cCE ccCEw ; aKR|G |CEi {vIuCEi
- 9j: VCs f- ^ OCC>| -z YS rSqbqf- >- ^@[ -qf , bbqPbCfG KC^Cq YSc@rb- ^@Css bH,, bqWb.. ] Czs R ? C-S@ 4YCi R'=, eeYs- zb^s - ^@ yPCbq%bHdCzqS ] Czs /CEH=|IzP R^zq^ -zb^ -Y; b^HqC^<C R , yd] /CEH>3bVL^->Rz Y%T- ^C/c /I>|CEI dqb<C@S^Lsi B@S@4%TbqS; bq- @CY - ^@,, bYH- ^L pCSSLi 3CqS^> OCS@YqL=refLcQ 3CqS^ OCS@YqL> |CE>e-LG c\_u |ci S4^=\_uDQ QJCE |uu\_{Qi @bS-cCEcCEw uDQ QJCE} uu\_{QJec|i ~qY=Pzes=ww@Si bqLwcCE cCEw uDQ QJCE} uu\_{QJec|i
- 9k: VCs f- ^ OCC Cz -Y a ^ zPC qYzb^sPSe 4Cz..C^ ..bqWb.. \ b@C^S - ^@ @b<-Q \ C^z z@Cs i R'=R^Hbq\ -zb^ r%szC s f|CEJg Ss^=CECEJ{u\_i @bS-cCEcCEvwU Ssi |CEi CEi CEi
- 9l: Xi [ i OSYP Cz -Y , eqS Cqb^ zPCdCzqS] Cz [ -qWe X- ^L~LC- ^@R^a wB; ci \_CEQ i R'=dCzqS] Cz ] C.sYzCq uv f|CEJg yPS- qS^C...s- Yb e-4YSPC@-z zPCyC^zP ,, bqWpbe - ^@y-zbqS Yb^ dq <zS- Y} sCbH, bYb-q@dCzqS] Czs - ^@ ; d] ybb^s f; d] CEg I q~s? C^ \ -qW^a zI |CE>eei cCEQ|CEe-LG \_ |D Ss^=CE\_cQDCEi
- 9m: V- qYO-eeYq yPC- qz bH4-S@S^L- lbb@4C^<P\ - qM C^Li R'=XCz-z-q/ bzCs S^ ; b\ e-zq r<S^<C fS^<Y@S^L r~4sCqS Xcz-z-q/ bzCs S^ , qS^ <S YR^zCYL C^< - ^@XCz-z-q/ bzCs S^ 3SbS^Hbq\ -zSsgID\_I f|CEJg B@S@4%q - \ 4S q Cz -Y> e-LG cD {CE

- 9 | : , ^- Rf ^<PSW, S<C^<b GCq\ C> ^@; G- qC d~z ssi 3d| CzCqF,, C4 sCqfSC  
 - ^@- eeY<- zb^ HbqsZ- zS- ^- Yss bHBd[ | |iC<bY<-zS^s i C^Li R^=; C-q,, bqWQ  
 sPbe d q<CC@^Ls cJcDf| CEI g-e- LGs { CE{ Ji Ss^=cvcc{ CEI{ i
- 9 { : R^Lq@TG <Y- ^@; Pqf; - qCq R^ yqf, @fSbq..Czq-sz=p- ^V^Ls<- Y- YzSfC  
 qLS G- ^@- 4szq <zS%zC s i R^=, <<b- ^z^L>a q- ^S- zB^s- ^@rb<SC%b| CEgJ  
 Ss^=CEvc{vD| i @bS=cCEcCEvwU - bsi | CEci CEi CEI i
- 9J : y- b TS^ Cz - Y B' <S^z - ^@, <<-q zC pCzqCf- YbH3~s^Ss d q<Css [ b@C^S  
 zPq-LP R^@C^S^L i R^= a ^ zPC | b fC zb | G ^S^LHYR^zCq^Cz r%zC^ s= a y|  
 /CECE; b^H@Cq zC@R^zCq^ zB^ Y; b^H@C^<C=; bbeR^>R^> a, - ^@a? 3, rB>  
 OCqsb^Ssbs>; qzC> KqCC> a <zb4Cq | I Q\_> /CECE d q<CC@^Ls> d- q R B @S^C@  
 4%pb4Cq [ CCq^ - ^>y P- q \ ? SYB^>- ^@ dS^q OCqCq i 3Cq^> OCS@C^Cq|=  
 re q^Lq 3 Cq^S OCS@C^Cq| CECE- LGs JCE JCEi S4^=\_uDQ QJ| Qv\_{JQ| @bS-  
 cCEcCEw\_uDQ QvJ| Qcv\_{JQ| €| Di ~qY=Pzses=ww@bSi bqLwcCEcCEw\_uDQ Q  
 vJ| Qcv\_{JQ| €| Di
- 9I : ? b^ Y@3i TbP^sb^i GS^@^L, YzPCBY\ C^z q% S^<-Ss bH ? S^<zC@Kq eP i  
 R^=rR [ Tb-q^ Yb^; b\ e~z^L Jic fc\_ul g-e- LGs uu Dji Ss^=CEEUQ\_{ui @bS-  
 cCEcc{uwCECECEi ~qY=Pzses=wwCe-4si sS- \i bqLw@bSwcCEcc{uwCECECEi
- 9v : a YfCqVbee Cz - Y yPC? S Cq^<C3Cz .CC^ Kq ePQ- sC@- ^@3Y^WQ zq- z- qC@  
 3~s^Ss d q<Css [ b@C^S^LX- ^L- LGs i R^=B| yBpdpR^B | a ? BXXR^ K , | ?  
 R^ Gap [ , yR^ ] r^ ryB [ r , p; ORyB; y} pB Jic f| CEgJ e- LGs { c i
- 9u [ i V- ^<C- ^@ [ i ,, GSVI 3CP- fSb-q Y| b@C^=Gq\ | b@C^S^L GS^SC, ~zb\ - z-  
 zb, ^- Yss^L 3~s^Ss d q<CssSi re q^Lq R^zCq^ zB^ Yd~4YSPS^L>| CEvi S4^=  
 \_uD { c\_JJ\_vCEi ~qY=Pzses=ww4bbW^i LbbLYG @W4bbW^ns@EOIB?k , k3, Ti
- 9D [ - zzPS s V~^<C> [ - zzPS s ,, CS@S^P>- ^@ [ - zPS s ,, GSVI 3CP- fSbq YsS. SY qQ  
 S%Q, eqpeCq \ Czq^ i C^Li R^=XCz-zC] bzGs S^; b\ e-zCq r<S^<CfS^<Y@S^L  
 r~4sCqS XCz-zC] bzGs S^, qS^<S YR^zCYLC^<C- ^@XCz-zC] bzGs S^ 3Sb^Q  
 Hbq\ - zSsgvD\_v f| CEgJ B@S^C@4%r zCH^SCpS^@CqYQ ->G q- W^yb- \ - ^S- ^@  
 V- qzC^ ,, bY^e- LGs cvv cDi Ss^=cvcc{{J\_>CECE\_u{i @bS=cCEcCEw\_uDQ Q  
 vJ| Q| { CE\_Q| €| i
- 9\_ : [ SPSPSp V-q \ b<PS- ^@KCbqLCV- q%Si GqD ~C^z s~4Lq eP @S- b fCq^i C^Li  
 R^=d q<CC@^Ls QRCC R^zCq^ zB^ Y; b^H@C^<C b^ ? - z [ S^S^L>R^@ f| CEgJ  
 B@S^C@4%q i; Cq b^>C y i ^ i XS^>- ^@† i ,, ~>e- LGs { c { | CE Ss^=| { uDJD>  
 cI CEuDi @bS-cCEccCEwR; ?| i | CEI \_D\_I { Ji
- 9CE [ - qC^S X- pbs- Cz - Y , dpa [ apB=, ^- @f- ^<C@eq<Css \ b@CqCebSzbq^i  
 R^=B^eCq r%zC s ..SP, eeY<- zB^s f| CEgJ Ss^=CEI ucuJi @bS-cCEcCEvwU  
 Cs..i | CECEc| i CE| i
- 9c : Vqsz^ 3S^L- q@X- ssC^ - ^@,, SY [ d f- ^ @Cq, - Yzi ; b\ eY^S%a CzqS Hbq  
 ,, bqWb..^Cs i R^=R^Hbq\ - zB^ - ^@rbH^.. qY<P^bY^L%ci { f| CEgJ e- LGs vcCE  
 v| vi Ss^=CEI CEDJ\_i @bS-cCEcCEvwU S^HbH | CEI CEI CEI

- Q |: , ^@C...XS >, CCQp^L a b^>- ^@,, C^4S ŠP~i , 4szq <z yb..: q@s ? C ^SSfC 3C^<P\ - qW^L bH, YlbSP\ dCqHq\ - ^<Ci C^Li R^=f|CEJ @bS-cCE ci ci D\_i J|cvi
- Q { : T- ^ [ C^@S^Li X] 3Rl v Q| CzSs Hbq dqb<Css / b@Csi req^L Cq QqYL 3CqS^ OCS@CqCq>|CEI
- Q J : 3i Ti yi [ bqL- ^ - ^@Xi ? Cfcb%G ] b^Q ^Hbq\ p- ^@b\ , - qz C K C^Cq zS^ i ~^@ R^=3Sb\ CzSs JJi{ fc\_DDg>e-LC\_c\_i Ss^=cI JcCE|CECE{Jc+i @bS-cCE |{CEwI{cvci i
- Q I : pC@CSL^S^L pC^LS^CqS^L zPcb-LP [ C s-q\ C^zQ qfC^ R^HqC^<Ci R^=/ R^ k ~- qCq%q\ iJ fc\_DDg>e-LG I CE I {Ji Ss^=CEuvuuD(i ~qY=Pzze=vw.....i Uszbqi bqLwsz- 4YCwJ\_II{i
- Q v : RPSp r~<-VŠ- ^@y- @b [ ~qz-i , \ CzPb@ Hbq szCe..SC qC^ ^C C^z- ^@- 4Q szq <S^ bHdCzS^ ^Cz i R^=Tb-q^- YbH; b\ e-zCq - ^@r%szC\ r<S^<Cs fc\_D|g Ss^=cCECEu|Ji @bS-cCEcCEvwCE|QCECED|g\_CEE\_Qvi
- Q u : pi y- qJ^i ? CeZPQ qz sC qP- ^@S^C qLq eP- YlbSP\ s i C^Li R^=rS\ Tb-qQ ^- Yb^ ; b\ e-z^Lci| fc\_u|g>e-LG sJv vCEcJv cvCESs^=cCEI uccc>CEul { \_ui @bS-cCEcc{uvCECECE
- Q D ,, i | idi , - ^ ? Cq , - Yz Cz- Y rb- ^@Css bH.bqWb...^Cz=: YssS <- zS^>@C-SQ - 4SS%w ^@- ^- Yss i R^=Gbq\ - Y, seCz z bH; b\ e-z^L |CEci S4^=CE{JQCE{i @bS-cCEcCEwsCEvl QCECEvcQJi
- Q \_ : VCGs [ i , - ^ OCC- ^@ŠPC^LXS i K^C^Cq zS^L 4C^<P\ - qW 4%q ^@b\ szCe..SC qC^ ^C C^z bHdCzS^ ^Cz i R^=: B} p ,, bqWpbe dqb<C@S^Li , bY\ CD|ui |CECE e-LG JCE Jcui
- Q CE VCGs , - ^ OCCz- Y ? S<bfCqS^L <P- q <Cqszs bHszb<P- szS <bYCzS^s bHeqbQ <Cz \ b@Csi C^Li R^=XCz-q ] bzCs S^ ; b\ e-zCq r<S^<CfS^<Y@^L r~4CqfCs XCz-q ] bzCs S^ , qS^ <S YR^zYLC^<C - ^@XCz-q ] bzCs S^ 3Sb^Hbq\ - zSg vD\_v f|CEcg B@S@ 4%arZCH^SC pS^@CqCQ -> G cb-Wyb-\ - ^S- ^@ V- qzC^ ,, bY e-LG |\_D {c|i Ss^=cvcc{{J->CECE\_u{i @bS-cCE cCEw\_uDQ{ QvJ|Q |{CE\_Q|€|i
- Q c : ŠPS S^L ^ - ^>pC\ <b ? SWW - ^> ^@d- ~YK qCE^i 3-s^Ss eqp<Cz \ b@CqCebS Q SbcfCs QCq\ C.bqW- ^@s-qfC%i R^=R^Hbq\ - zS^ - ^@r bH. : qCyC^P^bYL%JiJ f|CE|g>e-LG {DE{ \_i Ss^=CEI CED\_i @bS-cCEcCEvwLi S^HbH |CEci cci CEI
- Q | : ŠPS S^L ^ - ^>pC\ <b ? SWW - ^>- ^@d- ~YK qCE^i G sz 4-s^Ss eqp<Cz sS Q SY q%G qP i R^=? SzpS^<C@- ^@d- q YCY? - z 4 sCs f|CE|g Ss^=CE|vDuD|i @bS-cCEcCEwsCEvc\_QE|QuCE\_Q i
- Q f : ŠPS S^L ^ - ^>pC\ <b ? SWW - ^>- ^@d- ~YK qCE^i K^C^Cq zS^L eqp<Cz \ b@C^ <bYCzS^s i R^=r bH. : qC - ^@r%szC\ s / b@C^L cviJ f|CEug>e-LG \_u \_\_Ii Ss^=cvc\_c{uJi @bS-cCEcCEwsCEuCECEI QCE\_uQvi



9J: ŠPS S ^L ^ - ^>pC\ <b? SW - ^>- ^@d- ~YK qC^i K C^Gq zS^Ls%zPCzS eqp<Gss  
\ b@CY<bYC<zb^s ..SP edpeCqzSs bHY 4CC@ qC YQC \ b@Cš i R^=XC-z-q ] bzCs  
S^ 3~s^Css R^Hbq\ -zb^ dqb<Gss^Li B@zC@4%š i a~%š^L - ^@Ti ^ i T~^Li , bQ  
~\ CcDc X] 3Rdi req^LCqR^zCq^-zb^- Yd~4šPS^Lr..Sz CqY^@>|CEJ>e- LGs uJ  
DI \$4^=\_uD{|c\_@|c\_i @bS-cEcCEiw\_uDQ Q(c\_Q@)||Qvi

